THE UNIVERSITY OF CHICAGO

AN EXPERIMENTAL STUDY OF THE CHARACTERISTICS OF HANDWRITING MOVEMENTS WITH SPECIAL REFERENCE TO THE DURATION AND SPEED OF SUCH MOVEMENTS.

A DISSERTATION
SUBMITTED TO THE FACULTY
OF THE GRADUATE SCHOOL OF ARTS AND LITERATURE
IN CANDIDACY FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

DEPARTMENT OF EDUCATION

BY

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CHICAGO...ILLINOIS

DECEMBER......1922

7470

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ACKNOWLEDGEMENT

The author acknowledges his debt to those who kindly acted as subjects for the experimental work, and primarily to Dr. F.N.Freeman both for the basic studies which he has made and for his direct counsel. Funds provided by the General Education Board aided greatly in the providing of apparatus and also clerical assistance in the transfer and graphing of records.

The experimental work was carried on in the laboratory of the department of Experimental Education of the University of Chicago during the years 1917-18. The privilege of using this laboratory with its excellent equipment is greatly appreciated.

PART ONE

Presentation of the Problem and the Plan of Procedure also a Historical Summary of Previous Contributions.

The Problem and Plan of Procedure

The scientific study of handwriting in its earlier stages was of necessity largely concerned with isolated investigations of the handwriting process with a view to noting the specific characteristics prevalent and obvious in ordinary writing and in associated movements. In this way many discoveries were made which have proved very significant in the further study of handwriting and in the outlining of principles of method. Among such fruitful lines of investigation may be mentioned the various studies of inner speed relations which proved conclusively that, in normal writing, the speed of the pen point within the written line constantly varies, with the increase of speed at the beginning or end of strokes. The slant of movement was investigated and the medium forward slant found most favorable to economy. The written form, the type of instrument, the writing position, the pressure of the fingers upon the penholder and the penpoint upon the page, etc., have in the same way received attention.

The task which is facing the student in the field of handwriting at the present time is that of investigating more directly the problems connected with methods of teaching looking toward the most effective and economic results. To this end there must be systematic analysis and classification of the factors which influence the handwriting process and some adequate indication of the manner and the extent of their influence. This can be done only through intensive diagnosis of handwriting processes and products with a view to locating the blame definitely for characteristic defects, taking into

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consideration, of course, variations due to individual difference. Among such defects may be noted; excessive or insufficient length of strokes, difficulty in rounding curves at the end of strokes, lack of smooth even progression within the stroke, waste of time, etc. In the words of F. N. Freeman (5:181)

> It will still be necessary before we have solved all the problems which are involved in the teaching of handwriting, to carry on investigations which shall consist of an analysis of the form of writing, and of the movement and mental processes by which it is produced.

The ultimate aim will not have been achieved until methods of correcting faults, and especially instructing so as to avoid these faults, have been discovered and applied.

Most of the factors essential to good penmanship have already been isolated and dealt with, and many recommendations of good method have resulted, with altogether too small an effect on general practise as yet.(1)

Many recommendations, both general and specific, are made which are based on no scientific foundation, but are on the contrary merely matters of opinion. Among such may be noted the use of the metronome or phonograph as a guide to rhythmic movement in all types of writing and at all ages, the exclusive

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(1) For such a summary list of suggestive principles the reader should examine F.N.Freeman, "Principles of Method in Teaching Writing as Derived from Scientific Investigation" 18th Yearbook of the National Society for the Study of Education Pt.2, pp.11-25. In this article not merely the principle is given, but also the experimental or other proof on which it is based is summarized and located.

use of the arm movement, etc. These must be subjected to critical investigation and be found valid before being generally adopted.

This investigation is primarily concerned with an intensive study of certain elements of penmanship which are deemed fundamental and which are a subject of dispute or of uncertainty at the present time.

In Part II of this investigation, a definite experiment is described which is concerned chiefly with the function of rhythm, both spontaneous and imposed, in handwriting movements. A comparison is made between good and poor adult writers, and also between child and adult writers, and some facts are pointed out regarding the relations of finger and arm movement.

The following topics are considered in Part III, among others:

1. The place and value of rhythmic control in handwriting. This involves the distinction between spontaneous and imposed rhythm, and a study of the correlation between them and certain elements in the writing product and process, such as arm and finger movement.

2. The analysis of organization and coordination of speed of movement with a view to discovering characteristic differences between good and poor writers, and also between child and adult writers.

3. Temporal economy in writing or the saving of time in the construction of written forms, or in the passage between these forms, especially as related to factors of quality.

4. The degree to which habituation may obtain in the behavior

of individuals, and its significance in relation to quality of penmanship.

The principles derived from this part of the investigation verify the value of the method used. A distinctive contribution to method is therein attempted with the purpose of securing more accurately detailed analysis of the temporal characteristics than has before been possible. Typical cases are presented and suggestive find
possibilities of the method, and specific recommendations are included with regard to the continuation of the lines of investigation here begun.

In a sense handwriting may be considered as especially susceptible to objective measurement. The speed of writing can be readily reckoned in letters per minute, and, with the recent development of penmanship scales, a sample of writing can be graded for quality with comparative exactness. But though these measurements are valuable indeed to the teacher or supervisor, the scientific investigator has long realized the need of supplementing them with a more detailed knowledge of the inner speed conditions of the written form.

That there is a clear and direct relationship between the speed of movement within the stroke and the form of the stroke or of contiguous strokes has been so clearly demonstrated by Freeman, both in his earlier[(1)] and later investigations, that it cannot be doubted. There yet remains to be discovered in detail just what these changes are, and in what way they are definitely related under various conditions. For example,

(1) See p. 75 Reference 2: p.18 ff.

exactly what effect does the length of a stroke or the curvature of a stroke have upon the speed with which it is produced? Does the distribution of speed within the stroke relate itself to certain characteristic performance?

All diagnostic study of the writing itself incidental to this investigation is based on remarkably exact knowledge of the changes in the rate of movement throughout the entire line of writing and the comparison of these changes with variations of length, direction and time in the corresponding parts of the product, as well as with the type of product as a whole.

The plan here followed involves two separate lines of experiment: (1) A study of the natural rhythm in arm and finger movement at different ages, and the effect of the imposition of rhythm on movement; and (2) The development and application of a detailed method adapted to the analysis of the handwriting movement of good and poor adult writers, also of child writers. By this method a study is made of natural rhythm in simple and repetitive forms, as well as in the construction of more complex written forms, and again the effect of the rhythmic guide is noted. In addition, the organization of speed and movement within the stroke is considered, as well as factors in time economy and habituation.

Summary of Previous Investigations

RHYTHM

The study of rhythm in relation to behavior occupied quite a large place in the psychological investigations of the period, 1890 to 1905, the movements of the hand, finger, and arm being studied, as well as the general bodily functions.

Following this period of purely psychological interest was one in which the subject of rhythm received very little attention. In recent years, however, there has developed renewed interest in rhythm as applied to certain forms of behavior, especially with the practical view to discovering and attaining the most efficient methods and processes.

It is manifest that many of the early investigations have contributed results which are of general value so as to apply to many specialized activities. It is to be expected, however, that each of these special activities must receive special investigation on its own account if we are to discover the exact relationship which it bears to rhythmic movement. Facts which are accumulated with respect to the action of certain muscles or groups of muscles will not necessarily apply to the action of other muscle combinations at work upon a different product or under different conditions.

Definition:

There has come about a modification in the meaning of the term, Rhythm, itself, which tends to confuse the issues involved. In practically all earlier reports rhythm was considered as a matter of simple temporal regularity, involv-

ing an equality of successive periods of time, usually marked by some sort of pulsation or beat, or the ability to adapt one's functioning to such time periods either consciously or unconsciously.

Another view of rhythm relates to rhythm of a more complex type well expressed by Lavignac, as noted by Goedhart (7:859) "Rhythm is nothing more than division of time into equal or unequal, but always proportional fractions. Time is the absolute equality in duration of all notes of the same value. We can play in time while giving the rhythm in an incomplete manner; we cannot produce correct rhythm without playing in time." Christian (7:860) likewise states that "Rhythm is the regulated recurring motion made clear in music by the periodical recurrence of accent." Bolton (2:237) makes the matter a little clearer in his statement, "The conception of a rhythm demands a perfectly regular sequence of impressions. . . . . A member of the sequence may contain one or more simple impressions. If there are a number of impressions, they may stand in any order of arrangement, or even in a state of confusion, but each member of the sequence must be exactly the same in the arrangement of its elements." A variation of this type of interpretation has to do with the larger daily or even annual fluctuations, but that need not here concern us.

A more recent view has recognized the rhythmic quality of free flowing movement such as the movement of a stream or of an aesthetic dancer, with no definite regard to the temporal succession, but without clearly designating by what right

such movement may be called rhythmical.

The Origin of Rhythm:

There is general recognition among authorities of the importance of physiological factors as an explanation of the rhythmic impulse. There are, however, various interpretations as to what these factors may be. Some have correlated natural rhythm with fluctuations of attention and expectation without tracing these to their source. Many have recognized kinaesthesis as essential ty rhythmic reproduction; so Ruckmich (18: 359), using an introspective method, states that whatever material was presented for rhythmitization, "kinaesthesis was essential for the establishment of a rhythmical perception." When this perception was once established it could "be consciously carried, in the absence of any sort of kinaesthesis, by auditory or visual processes." This experimenter does not, however, declare what was included in the definition of the term "kinaesthesis" as he used it, or what it was that the subject felt in his individual accomodation to the rhythm.

Mach (16: 413-4) made the most important early contribution to a motor explanation of rhythm in 1865, and was followed by a long line of experimenters who favored this explanation. Wundt (16: 414), though favoring the motor factor, never placed great emphasis upon it, but Meumann (16: 415) gave greater place to this explanation, though considering it as secondary and derived. Bolton (2; 234-6) placed great emphasis on the motor aspect of rhythm, especially "motor accompaniment", and even inclines to the motor interpretation.

He declares that "most subjects felt themselves impelled by an irresistible force to make muscular movements of some sort accompanying the rhythms." If the movements of one muscle were restrained they were likely to appear somewhere else. Such inhibition also interfered with keeping account of the rhythm. He further asserts that the muscular movements and associations were the conditions, not merely the results, of the rhythmical grouping.

Since the time of Bolton (1894) the general acceptance of the motor explanation has advanced rapidly. Miner (9: 30) favors the theory of the "muscle wave" as the basis for rhythmic grouping. He found that, while movements made by involuntary muscles coincidental with a rhythmic stimulus would be somewhat modified and adapted so as to cover a group of stimuli, and while the muscle wave would vary slightly at different times in the same individual, the general tendency was for the wave to be quite stable.

Stevens (17: 26), finding that the vaso-motor wave coincides, in at least 50% of the cases, with the fluctuations in judgment of a time interval, states, "There is no special Time Sense in consciousness; but our judgment of time is mediate, depending upon organic processes, of which the changes in blood volume is one of the more important." The best and most frequent coincidences of judgment and of vaso-motor wave was found to accur in fluctuations ranging from .4 seconds to 2 seconds apart.

Nichols (11: 529) early stated that the "later investigators look to physiological processes for explanation

of time-judgments, and particularly to rhythmic habits of nerve centers." Those who have still later studied the problem have given clearer definition of these habits, and have located their source more exactly as intimately bound up with the circulatory and respiratory functioning of the body.

The Ability to Follow an Imposed Rhythm:

In line with the above findings practically all experimenters agree that there is generally a "more favorable rate" of rhythm for each individual to follow, or at least a range or rates within which he is able to follow a rhythmic beat comprehensively.

MacDougall (8: 97) states that a particular "auditory series cannot be grasped at all if their succession falls below a certain rate, for beyond this limit the human consciousness has no capacity for rhythmical integrations of its impressions. When their succession rises above a certain other superior limit the numerical apprehension of the series of impressions again becomes confused." He found the total range of rates which could be successfully followed was from .1 seconds to 2 seconds with the most favorable rate for any individual one that was slightly more rapid than that adopted in free rhythmical tapping. He explains this fact by the presence of a greater inertia in the latter activity. He believes the upper and lower limits as above noted are fixed by the physiological laws which condition motor discharges and the limits placed on the discrimination of refined experiences of strain.

Squires (15: 575) similarly found that if the rate was too rapid there was no perception of rhythm. Bolton had explained this fact by stating the rate was too rapid to find muscular expression, but Squires asserts (p 577) that it is much more probably that it is because the rate exceeds the upper limit of the cortical rhythm. This investigator noted the upper and lower limits that could be well followed as 1 second and .1 of a second respectively, with the most favorable rate between .3 seconds and .6 seconds, corresponding to the bodily rhythms.

Nichols (11; iv- 529), in summarizing the findings of a long line of investigators states that nearly all, under all conditions, found "a particular length of interval more easily and accurately to be judged than any other", but that the "indifference point, or interval of best judgment is very variable for different individuals and for different times and conditions." The same author, while recognizing (11:iv-84) the fact that there is an individual norm for each person to which he tends to revert, found that practice "seemed to preserve its effect with nearly, if not entirely, its full force" for a period of about two minutes.

Wallin (18: 210-11) also noted the great individual differences in the choice of a preferred time, ranging from .305 seconds to 1.37 seconds with an average of .519 seconds. He found it possible to classify his subjects into slow, medium, fast and rapid groups.

Many have noted the constant error incident to the attempt to follow an imposed rhythm. Dunlap (4: 411)

found a tendency to drift away from the rhythm, then back, with the subjects either strongly positive or negative. Nichols (11: 529) presents a principle in explanation of this latter characteristic: i.e., in single norms and reproductions the constant error is minus for intervals longer and plus for intervals shorter than the indifference point, while in multiple norms the reverse is true. In other words, in the simple beat the subject tends to lag behind the imposed rhythm when it is beating faster than his normal response, while, when the stimulus is a compounded rhythm he will tend to push ahead of the more rapid beat and lag behind the slow beat. This authority does not agree that the judgment of the time of movement follows Weber's Law, or is the result of a fixed periodicity.

That the complexity of the rhythm has much to do with the success or failure of any attempt to follow it is almost axiomatic. Allbutt states (1: 340), "the simpler and ruder the musical sense, the more brief .... must be the recurrent rhythms .... the more relieved and elaborated rhythms of Bach and Beethoven need a more sustained attention and more cultivated apprehension, while the rhythms of Wagner are so postponed in their resolutions, and so broken in their variety, that perhaps few even of the good musicians can follow them with any consciousness of muscular measure or even of 'form'."

Sears (14: 43-4) has noted that the majority of child subjects got all the rhythms imposed. He determined that

age was an important factor in rhythmic adaptation, the increase in ability to follow or express rhythm by tapping being quite rapid up to the age of 9 or 10. After this age the progress was slower up to the age of 15 or 16, when there was possibly a falling away in skill.

Effect of the Imposition of Rhythm:

Scripture (9: 93) has stated the principle that, when natural rhythms and periods of work are made to coincide, one gets the most action with the least fatigue. Fere (Ibid) noted that fatigue was very rapid following increase of work in conjunction with certain rhythms. Miner (9: 95, 102-3) found that slow workers were aided by a rhythmic beat which was fast enough to stimulate them, while fast workers were hindered. Thus we see that the imposed beat would be effective in negativing the effects of distraction in some cases, but would produce distraction in other cases. Nichols is convinced (11: iv- 79) that a more or less permanent central habit is induced during practise with a certain rhythm, as a result of his experimentation with beats longer and shorter than the subject's normal rate through brief and extended practise periods.

Handwriting as a Form of Rhythmic Behavior:

Although there has been a great increase in the application of the principles of rhythm to handwriting, and there have been widespread recommendations regarding its use as an imposed guide, very few workers have approached the main or

related problems from a scientific point of view. It is not yet known to what extent the use of an imposed rhythm is an aid or what should be the strict limitations placed upon it as to age adaptation, rate of beat, complexity of rhythm, etc., or with what type of movements it may best be associated. Before this can be fully accomplished we must know to what degree rhythm is characteristic of best performance.

Freeman (16) and Nutt (12) have been the principal investigators of the value and use of rhythm in relation to handwriting, and are in general agreement in their results. Nutt (12: 155-6) arbitrarily measures the degree of rhythm "by weighing three considerations, namely, the largest number of strokes made in the same length of time, the number of groups into which the duration of the strokes fell, called the time groups, and the range of the time groups....... The total grade for rhythm was found by multiplying together the respective grades for the three items just given." Freeman (6: 11) considers rhythm as "an approach to equality in the time taken to write successive strokes". While this definition is a purely arbitrary one as applied to handwriting, it is in harmony with the simpler comprehension of the term as generally used.

Both of these investigators find rhythm strongly correlated with age, with ability to use and follow rhythm quite marked at the age of from 9 to 12. Freeman states (p.125) that the duration of the strokes becomes more uniform as the child grows older, and that it is more uniform in rapid than

in slow writing. Nutt, however, asserts (p. 443) that the speed of writing cannot be forced ahead of the natural development of rhythm without detriment to the form. Neither of these authorities find rhythm correlated with accuracy of form in such a degree as to induce a belief that they are in any sense interdependent. In fact it was found that a tendency to follow a rhythmic pace would tend to cause a slurring over of important elements in written forms. Nutt did not find that the rhythmic power was aided or interfered with appreciably by emphasis on the use of arm movement. Freeman refers to N.K.Smith in recommending rhythmical drills for the development of coordination, care being taken that the rate chosen is not beyond the capacity of the pupil, and his stage of quality development. No specifications are made, however, as to what these drills should consist of, or as to their age placement.

ACCURACY OF MOVEMENT

Errors of movement to which most of the defects in writing may be attributed are classified in two groups; those due to faulty perception, and those due to motor defect, or the inability of the muscle to perform the act intended. Fullerton and Cattell (19: 12-14) not only analyzed error of movement in this way, but weighed the error as due to these two causes, and came to the conclusion that the error of perception was considerably larger than that of motion proper. In other words, after a clear image was gotten of what was

to be done the tendency of the muscle was to perform with little variation the task thus clearly outlined. It is probable that too little attention has been given in the way of experimentation to the perceptual factor in handwriting.

Munsterberg (19: 15) however, notes a source of error which intervenes between perception and performance: "emotions can be sources of inaccuracy in our movement .... it is not improbable that many of the unaccountable variations in accuracy which often appear are the result of fleeting emotions." The line of attack here suggested has never been thoroughly or satisfactorily investigated, largely because of the difficulties connected with any attempt to isolate and weigh the consomitant feelings.

Bryan (3: 189-196) studied the development of children of the ages 6 to 16 in rapid and accurate movement. The growth in accuracy was most evident, comparatively in the years 6 to 8. The maximum rapidity he found remarkably constant in the same individual when using the same group of muscles, but the accuracy of movement was subject to much wider variations. This investigation does not, however, yield unqualified results, as the speed of movement was not controlled or recorded in those cases where accuracy was judged and the relationship was not clearly established. (19: 16). Bryan (3: 199) suggests that a critical test of voluntary control would probably be the maximum rate of voluntary rhythmically repeated movement.

Woodworth (19: 39-44) has shown that the duration of

the interval of rest preceding a stroke has much to do with the accuracy of the stroke itself. In general he concludes that "the accuracy diminishes as the interval is prolonged" (p.39) and that the short interval is conducive to a greater degree than the long interval "to an accurate adjustment of the initial impulse", (p.42) hence to a more effective current control within the stroke. Munsterberg's findings seem to disagree with this, but he did not deal with intervals of less than 2 seconds duration. (p.43) Woodworth is of the opinion that there is a point of maximum accuracy reached when the interval is shortened to at least .3 or .5 of a second or more. He further assumes (p.44) that there must be a turning point somewhere, and that the accuracy cannot continue to increase down to the interval zero. However he furnishes no evidence.

The uniformity which already appears in automatic movements, and which is a great aid to accuracy, he believes is favored and increased by high speed unless the rate is carried to such a degree as to interfere with the current control. The momentum within the stroke which is most favorable to uniformity of product he believes is assisted by easy, rhythmic movement as well as a short interval preceding the stroke.

Other inferences which Woodworth presents that are of significance to our discussion are: (19: 42)

1. "Any sort of movement in which the current control is so imperfect that the accuracy depends mostly on the initial adjustment will be expected rather to gain than to lose

from hastening the beat of the metronome (which is being followed). The resulting increase of speed would then do no harm, while the decrease in interval would do good."

2. Any movement whose "initial adjustment has to act in opposition to the momentum of uniformity" or, in other words, in which the current control is primary while the interval of rest preceding is incidental, will lose accuracy very rapidly as the beat is hastened.

According to this diagnosis, therefore, the use of the metronome or other rhythmic stimulus must be adapted to the peculiar nature of the movement, and by inference, to the typical movement habits of the subject, hence is not always applicable to any movement by any individual under any conditions.

Authorities are generally agreed that the increase of speed tends to increase the length of stroke, while decrease of speed will shorten the stroke. Woodworth notes (19: 38) that while changes of speed do not influence the average error when the eyes are closed, faster movements are, almost without exception, too long, the slower too short.

Freeman shows (6: 5) that strokes widely differing in length may be made in the same, or nearly the same, length of time, and states that this is a manifestation of the disposition to follow a rhythmic impulse in handwriting movements. There may be, therefore, an inverse accomodation of speed to length of stroke, or vice versa, in order to maintain a particular rhythm. Freeman also points out (Ibid) that the complexity of the stroke itself, as well as the strokes that precede and follow it, affect the duration of the stroke

and the speed with which it is made in its different parts, therefore must serve to modify the rhythmic character of the motion.

Bryan agrees (3: 150) with Freeman in noting that the extent of the movement has small influence on its duration, The medium sized strokes being executed more quickly than long or short ones. One should keep in mind, however, that this refers to straight strokes. Loeb (19: 10) the prime basis for judgments of the extent of movement is the duration of the movement, and while this statement is not quite in accord with that of Fullerton and Cattell who say (19: 10) that the duration of the movement is much less accurately judged than the extent, the two are not in opposition. In case the former statement were correct it is evident that the introduction of regular rhythmic habits of movement would tend to increase the evenness of the length of strokes. This would be true, however, only when the strokes were repetitive, with a certain rhythm and the various lengths of stroke associated without exception to a particular rate of rhythm.

Another factor of inaccuracy is attention. Regularly, when special attention is given to the making of a stroke both the length of the stroke and the speed with which it is made are decreased.

ORGANIZATION

By this term is meant, either the relationship between the various successive strokes, or the portions of the same

stroke both as to speed and length as well as form. It is generally considered in connection with the term, "coordination". A sample of writing which gives evidence of a free flowing movement in its construction is spoken of as showing good coordination without taking into consideration the perfection of form according to any recognized standard of penmanship, while lines which are irregular, showing abrupt changes in direction, or wavering and unsteadiness of progression are termed uncoordinated even though the writing itself be quite legible and well formed. But two samples of writing may be equally coordinated in these respects, and yet show entirely different types of organization. One may divide the different strokes into separate units of movement while another may execute the writing more nearly as one continuous movement with the changes in speed not so noticeable from stroke to stroke.

No one has investigated this field so throughly as Freeman (6: 2) and he may be referred to at length. He notes that good and poor writers differ greatly in the way they organize their writing as to "units of movement", the good writer generally making a more definite differentiation, which means merely that he does not tend to slur over any of the unit strokes involved, but, on the contrary, tends to give to each its full emphasis. It may at first appear difficult to reconcile this statement with another statement of the same authority (p. 11); "it may be taken as well established that the child's writing movement is divided more markedly into a series of separate or distinct movements than is the writing of the older person", and especially so since the child is gener-

ally a poor writer, judged according to best adult standards. The explanation lies in the fact that the child has not yet learned to round his curves evenly and tends to treat his writing as a group of successive straight line strokes. The young child also writes with much better form relative to his total skill than does the older person. The facility which is later gained in curved movements may be a hindrance to the attainment of quality if carried to such an extent as to fail to recognize the individual oval or straight line characteristics of the respective strokes. The unit recognition of the good adult writer is quite different in character from that of the child, since it evidences a clear connection between successive movements as well as a definite regular progression within each unit.

Freeman states quite clearly, and gives evidence to show, (5: 94-5) that the good writer adjusts his changes in speed to the character of the form which he wishes to produce, and also notes in this case a "certain regularity and smoothness of movement, which is represented, for one thing, by a similarity in speed in the strokes which are similar in character, and by a lack of suddenness and abruptness in the transition from slow to rapid movement."

SUMMARY OF PRINCIPLES PERTINENT TO THIS STUDY:

1. In speaking of rhythm in handwriting one should distinguish carefully between the various types of rhythm, and define his usage clearly in terms of simple temporal succession, recurrence of accent with broken time, or as free flowing

movement.

2. The natural rate of temporal rhythm for an individual is determined by deep-seated physiological tendencies, and this tends to remain constant.
3. There is a more favorable rate of rhythm which each individual can best follow, and individuals differ greatly in the rates which they most readily follow.
4. There is some evidence to show that a "foreign" rate of rhythm may be acquired, by practise with it, but there is no evidence to show whether this acquisition might be permanent, or to what extent practise must be carried to make it permanent.
5. An imposed beat, which is faster or slower than the natural rhythm of the one who is attempting to follow it, is conducive to error in the accuracy with which it is followed.
6. A complex rhythm is less easily followed than a simple rhythm.
7. The ability to follow a rhythm increases with age quite rapidly to about the 10th year, then slowly to about the age of 16, after which there is probably a loss in skill.
8. The imposed rhythm is of value as a guide in motor activity because of its influence toward a maximum of activity with a minimum of fatigue.
9. Only the slow workers are aided and stimulated by the use of an imposed rhythm; the rapid workers probably being hindered.
10. In the construction of written forms the tendency to make

successive strokes in the same length of time (temporal rhythm) increases with age.

11. Speed of writing favors this type of rhythm.
12. Temporal rhythm is not definitely correlated with good form, in fact may in certain cases prove a hindrance to it.
13. Rhythmic power is not affected appreciably by use of arm movement as compared with finger movement.
14. Children increase more rapidly in speed than in accuracy of movement. The latter is also subject to wider variations.
15. The lengthening of the interval of rest preceding a stroke tends to decrease the accuracy with which the stroke is made, though it is possible that this may not hold true of intervals of less than .3 seconds.
16. Speed of movement is favorable to accuracy unless carried to a degree beyond the limit fixed by natural habits.
17. The following of an imposed rhythm will assist in accuracy of movement only those who have such poor motor control as to need a stimulus at the beginning of the stroke in order to carry them through it successfully.
18. The imposed rhythm, when used, should be adapted to the particular needs of the individual, otherwise it is surely an artifical factor in the situation.
19. The increase of speed tends to lengthen the stroke.
20. Strokes of greatly different length may be made in about the same length of time.
21. The complexity of a stroke affects the temporal characteristics of that stroke and neighboring strokes.
22. It is probably that there would be less variation in the

length of strokes with the acquisition of good rhythmic habits.

23. The chief elements of good coordination and organization are

(1) organization of the line of writing into units of movement.
(2) arrangement of division points between units to correspond to the form being constructed.
(3) execution of each unit in a well coordinated manner with the greatest speed in the middle of the stroke and a correspondence between speed and length and simplicity of the stroke.
(4) consistency, or the production of successive strokes with similar speed changes, due allowance being made for changes in form.

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PART TWO

AN EXPERIMENTAL STUDY OF RHYTHM IN HANDWRITING MOVEMENTS

PURPOSE:

The experimental study herein outlined was undertaken as a preliminary study to the more detailed analysis of Part III. In this experiment the chief consideration is the discovery of time relations which obtain in typical movements such as are used in handwriting. Each stroke is considered as made up of two elements, Rest and Movement. Not only are these periods compared with each other as to duration but successive strokes are also compared to note the regularity of the time factor.

The records of 48 subjects are here collected and analyzed; 24 of these being adults, evenly divided into good and poor (1) writers. The remaining 24 are children of whom half are less than 11 years of age and the other half above 11 years of age. These subjects were selected according to this grouping with the expectation of finding results bearing upon factors significant for good penmanship and age development.

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(1) This division was made on the basis of the following considerations:

1. General appearance, and grade on the Ayres Scale, the good writers being graded at 75 or above, the poor writers falling below the grade of 60.

2. Specific characteristics as evenness of line, uniformity of spacing, and especially coordination which were present to a marked degree in the writing of the good writers and notably lacking in that of the poor writers.

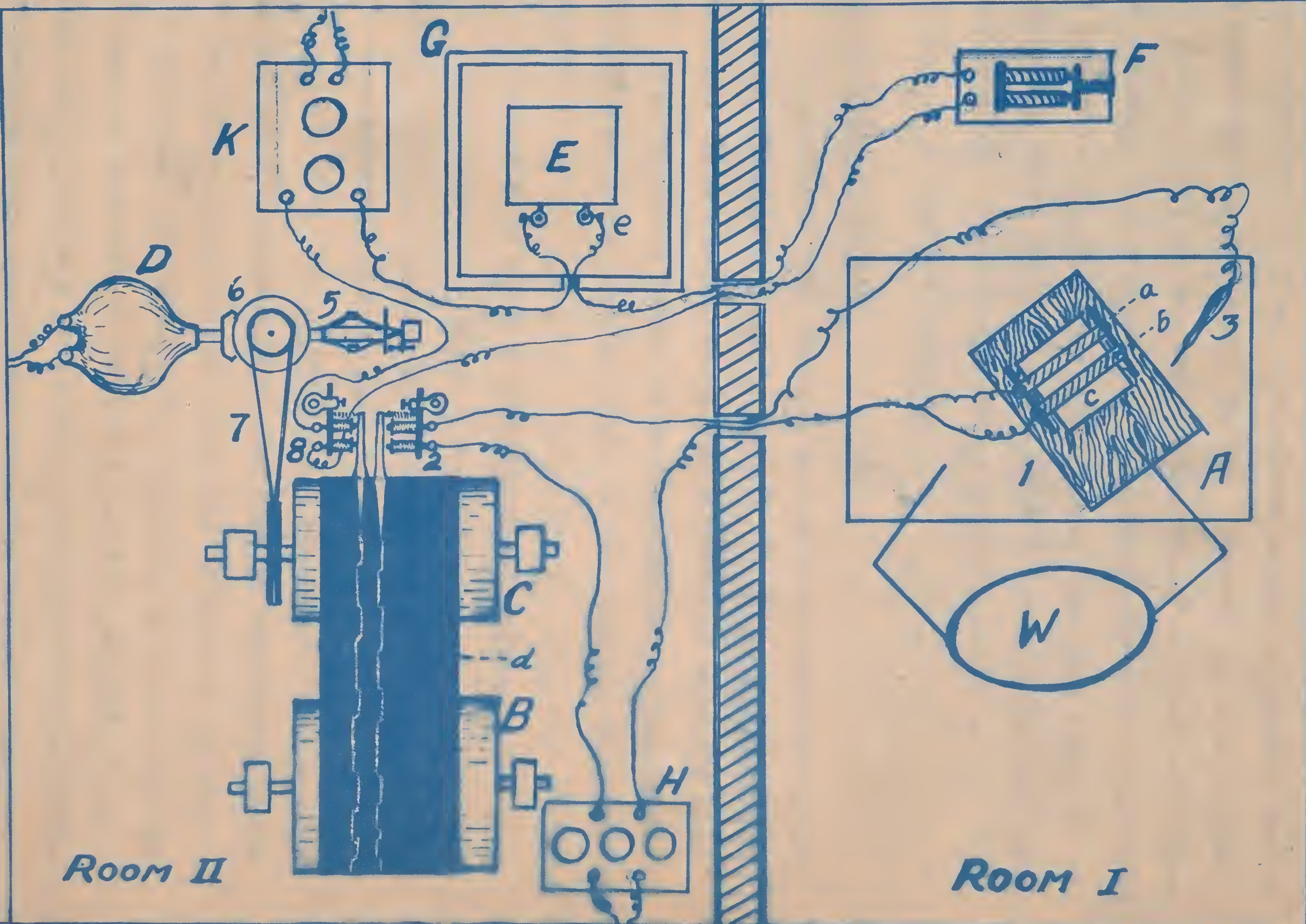

FIG. 1 SUPERIOR VIEW DIAGRAM OF APPARATUS FOR THE STUDY OF MOVEMENTS USED IN HANDWRITING

Each subject was tested for his characteristic behavior under conditions of free, spontaneous choice of rhythm, and in the following of an imposed rhythm. Records for each subject were gotten while he was emphasizing finger movement and these were compared with another set of records made while emphasizing arm movement. In this way it was hoped that data would be accumulated which would show the significance of the two types of movement in relation to natural rhythm as well as in response to a rhythmic stimulus.

APPARATUS AND METHOD.

The apparatus used in this part of the investigation was especially designed to give a graphic representation of the time spent in a stroke, or in its elements of rest and movement, on an extended scale, so that approximately the exact amount of time taken in each phase of the movement might be computed.

In Figure 1 is given a superior view diagram of the

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Figure 1. Showing Arrangement of Apparatus for Study of Handwriting Movements.

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apparatus and its connections. The subject was seated in the position indicated (W) at the table (A) in Room I. On the table was placed conveniently the board (1) which had fastened to it the two thin brass strips (a) and (b), adjusted to a distance about one half inch apart, overlying the glass plate (c). Both of these strips were connected through a lamp battery (H) with a small electro magnetic marker (2) in Room II,

and the stylus (3). The stylus was connected with the electric circuit by means of a very pliable wire which would not interfere with the freedom of movement of the stylus. When this stylus, being moved to and fro between the strips as in a writing movement, came in contact with either of the strips at the end of a stroke, an electric connection was established so as to move the marker point and hold it in that position until the circuit was broken.

The record of the movements of the marker point was made on a belt of smoked paper (d), running over the two kymograph drums (B) and (C). These drums were driven by the electric motor (D), the speed of which was automatically controlled by the governor (5). Suitable rate of movement of the recording surface was obtained by the use of the gear (6) and the belt and pulley connections (7).

The subject was advised to move the stylus to and fro between the strips in a natural vertical or slant movement, taking care to make contact with each strip, until notified to stop. He was allowed a few minutes practise before the record was taken.

Provision was made for analyzing the subject's behavior in following the beat of a rhythmic stimulus in the following manner. A simple rhythmic beat was provided by the use of the metronome (E) and was recorded by means of a second electro-magnetic marker (8) placed in circuit with it through the lamp rheostat (K). Electric contact between the pendulum of the metronome and the marker was made through the mercury cups (e), which were set in such vertical relationship to

each other and the points of the plunger bar, attached to the pendulum that successive contacts were equally spaced. It was found that the best of the metronome did not synchronize exactly with the electric contact, and in order to obviate this difficulty, a telegraph sounder (F) was introduced into the circuit. This instrument was placed near the subject in Room I and so adjusted that a distinct click would be produced at each electric contact of the metronome pendulum. In order to prevent any confusion between the two types of stimuli, coming from the metronome and sounder respectively, the former was placed in a sound proof container (G) in Room II.

Simultaneous records were made, as indicated in Figure 1, of both the rhythmic stimulus and the reaction of the subject to the stimulus. Care was taken to see that the two records were directly comparable in time by advancing the two marker points to corresponding positions on the face of the drum. The regularity of rhythmic action of the metronome, also the exactness of the time interval, were tested and insured by comparison with the record of a standardized tuning fork. Four records were made for each subject; one each of finger and arm movement, the subject setting up his own rhythm, and one each of finger and arm movement, the subject following an imposed rhythm.

The records of imposed rhythm always followed those of spontaneous behavior in point of time so that no kinaesthetic or memorial impression of a practised rhythm might be carried over and serve to modify the spontaneous character of the subject's movement. The subjects were evenly divided into two

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And [illegible]

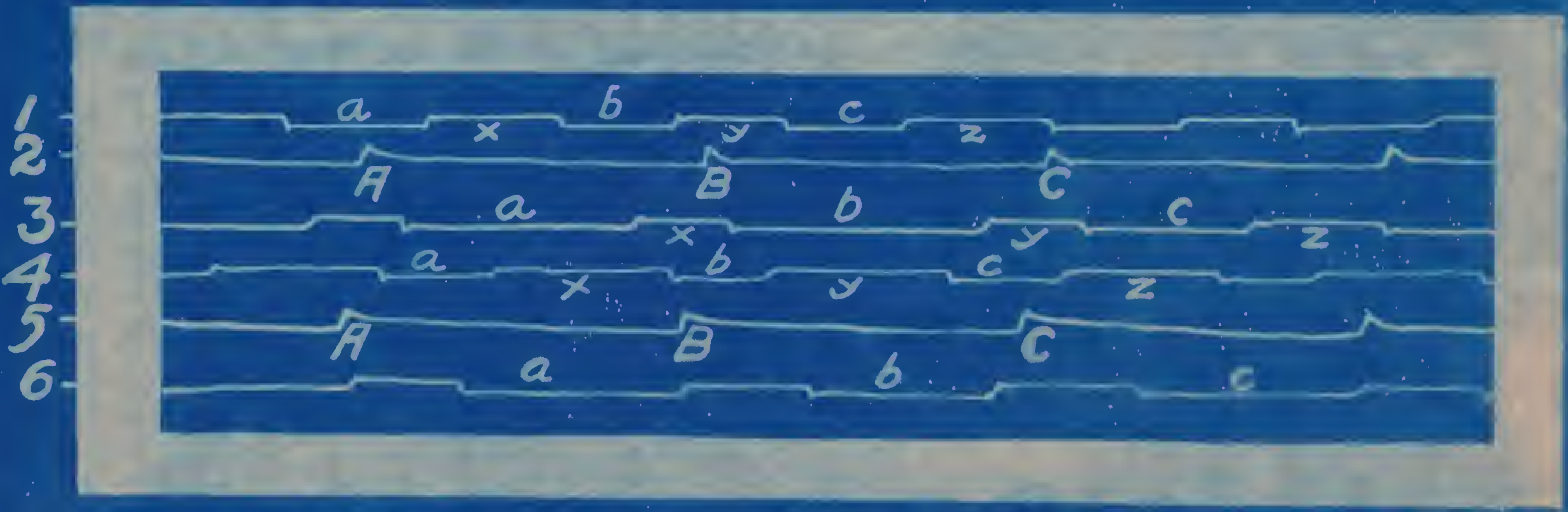

FIG. 2. Section of a Typical Record

groups. The one group used the finger movement preceding arm movement in both spontaneous and imposed rhythm, while the other group used the arm movement preceding finger movement. This was done in order that the records of each group might be used as a check upon the records of the other, especially with reference to any possible influence that practise with the finger and the arm movements in any order might have.

A portion of the original records of one individual is reproduced in Figure 2, each record being numbered according

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Figure 2. Section of Typical Record

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to its order of arrangement as follows:

1. Spontaneous finger movement
2. Rhythmic beat followed by subject in making record #3
3. Finger movement with imposed rhythm
4. Spontaneous arm movement
5. Rhythmic beat followed by subject in making record #6
6. Arm movement with imposed rhythm.

In the case of the records of the finger movements (1 and 3) and arm movements (4 and 6) the sections (a,b,c,etc.)represent the relative amounts of time spent at rest at the end of successive strokes; the lengths (x,y,z,etc.)represent the time of passage from the beginning of each stroke to its terminus. The sums (s plus b, y plus c, etc.) therefore represent respectively the total time taken from the beginning of one stroke to the beginning of the next, while the sums (a plus x, b plus y, c plus z, etc.) represent the total time taken from the completion of one stroke to the completion of the next.

In the records (2 and 5) the points indicated by the

letters (A, B, C, etc.) note the incidence of the beat. An examination of the records (3 and 6) shows that the lengths (x plus b, y plus c, etc.) fairly correspond as to lengths and limits with those of the rhythmic beats (B to C, C to D, etc.) in the records 2 and 5 respectively.

Records were measured as follows. A millimetric rule was laid along a record and the length of a section indicating the amount of time spent at rest was noted and measured in millimeters, also the total distance from the beginning of this period of rest to the beginning of the next period of rest, this being the total stroke. The difference between these two measures was also noted as indicating the comparative amount of time spent in the movement proper. The space between the beats in records 2 and 5 was noted as a test of regularity. The distance between the incidence of the beat and the beginning of the rest period in the movement following imposed rhythm was noted also. In case the subject were following the rhythm perfectly it is evident that the beginning of the rest, (x) should fall directly below the point (B). In case the deviation of the subject was due to lagging the measured difference was indexed with a minus sign. All measures were noted to the nearest millimeter, no fractions being considered. A group of fifteen successive measures, x plus b, y plus c, etc. were made from each record of any subject the starting point being selected at random. It was found that increasing the number of measures beyond fifteen did not serve to alter the general results or conclusions in the various records so dealt with whereas a smaller

number, such as ten, introduced noticeable variations.

The measures of the records of each subject were tabulated as shown in Table 1 in the Appendix. It should be kept in mind that these measures in terms of millimeters are merely spatial representations of time elements. All measures of this type will be noted henceforth with the index symbol (m) following, to indicate the use of the linear, millimetric unit of time.

The computations made for each subject were: The average (Mean) length of time spent at rest, in movement and the total stroke; the mean deviation of the unit measures in each of these cases; the per cent deviation, or the average variation divided by the average duration; the positive or negative trend of the deviation from the metronome beat; the total deviation and the per cent deviation, including positive and negative cases, from the beat of the metronome; and the per cent of time spent at rest. These computations were made for both finger and arm movement, and for spontaneous (except the 3rd and 4th items) as well as with imposed rhythm.

The question of the reliability of the measures called for special attention. Occasional use of a standard tuning fork and marker on the drum showed that the range of variation in the speed of movement of the drum in the making of two records at different times was less than 10 per cent while within the same record the regularity was quite constant with none exceeding 2 or 3 per cent of variation. Hence, although the comparison of actual measures of a series is

slightly misleading, the comparison of the derived per cents of deviation of each subject from his own record average with the similar accomplishment of others is justifiable from the standpoint of reliability. In the case of movement with imposed rhythm the rhythmic beat was provided as a check, but the difference was so small as to be negligible.

The tendency for any individual to vary from his own record in subsequent trials was tested in the case of four subjects with the purpose of discovering the reliability of a single record as a type of the individual's behavior. These results are shown in detail in Table 2 of the Appendix. They exhibit a remarkable consistency for these subjects. Although the various subjects differed in their succeeding record to a marked degree in some cases, yet the extent of agreement throughout is indicative of typical performance for each. In Table 1 a comparative summary is shown which

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Table 1.

The Tendency for Individuals to Vary from Their Own Records (1) as Compared with Their Tendency to Vary from the Records of Others of the Group (2)

Individuals.	Total Per Cent Variations (A) Average measures of duration	(B) Per Cent of Time Spent at Rest
(1)		
W.	9.5	7.8
F.	14.3	10.5
C.	12.2	16.3
P.	17.5	9.1
Average	13.4	10.9
(2)		
W of F	32.5	9.6
W " C	20.5	22.2
W " P	9.5	7.7
F " C	50.7	25.3
F " P	38.5	12.4
C " P	15.8	19.4
Average	27.9	16.1

may be interpreted as follows: The records of subject W in two trials were analyzed and the total per cent variations made from his own record in the Rest, Stroke and Total periods with Spontaneous movement were found to be 9.5. His per cent variation in the per cent of time spent at Rest in both Spontaneous and Imposed Rhythm was in the same way found to be 7.8. In the same way each group of records was analyzed for each individual. In (2) W's record on one trial is compared with F's record on one trial and the per cent variation found, and so on through all the possible combinations.

It is noteworthy that the average deviation of the individuals from each others' records is from 60 to more than 100% greater than the average deviation of the members of the group from their own records. There is a general similarity of records for the few members of this group, however, which may be attributable to the fact that the subjects dealt with represent rather a unified body of adults. All were good writers whose writing showed about the same grade on the Ayres Handwriting Scale and whose writing movement was characterized by free flowing strokes and, in general, a consistent performance. Such similarities suggest questions regarding characteristic performance which is later considered under the topic of habituation (p.146 ff.).

It could hardly be expected that an individual would continue constant in his record day after day, unless he had developed definite habits of movement and the conditions of his environment, physique and mental attitude remained the same. In case such variation were great enough to call into

question the results of a single record in point of view of reliability, the averaging of two or more records would be necessary. The inclusion of a number of subjects in the experiment would tend to neutralize the effect of chance variations of any individual from his own preceding or characteristic behavior, since the chances are even that the cumulative variations below the true type would be equal to those above. Furthermore, any persistent difference between the records of the members of a group, or the average of the group, and those of another group, would tend to indicate an actual significance in the measures hence may be considered an index of reliability. Such group differences were found clearly marked as will be noted in the following pages.

Table 3 of the Appendix gives a compilation of the average measures of all the subjects that were examined in this experiment. Group One of the Adults was made up of writers who might be generally termed "good writers" according to the scientifically accepted standards. All wrote very legibly with good clearly formed characters, and with free flowing movement, and steady progression within the stroke. Group Two of the adults was selected because of poor penmanship judged according to the same standards. Some of the poor writers were fairly legible writers, but the written forms were poorly shaped and the stroke seldom regularly constructed. Group One of the Children is made up of younger children ranging in age from 4 years, 10 months to 10 years, 10 months, with an average age of 8 years, 11 months., while Group Two is composed of those from 11 years to 17 years,

3 months, with an average age of 14 years, 10 months.

In Table 2 below a summary table is given in which only the averages for the respective groups are given. It should be noted that these are the measures of duration expressed in linear millimetric measure. The records for finger and arm are compared for all groups as to the length of time spent on the rest period preceding the movement, also on the stroke period or the movement itself, and the total period made up of both the preceding. Those wishing to acquaint themselves with fuller detailed study of individual records

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Table 2

Summary of the Average Records of Good and Poor Adult Writers and Younger and Older Child Writers in Duration of the Total Stroke and Elements of the Stroke Without and With Imposed Rhythm (in terms of M).

		Rest		Stroke		Total		
		Fing.	Arm.	Fing.	Arm.	Fing.	Arm.	
	(Good	17.	12.9	19.7	22.7	36.7	35.6)	
Adult	(Poor	16.9	13.	18.1	21.1	35.	34.)	Spontan.
	Average	16.9	12.9	18.9	21.9	35.8	34.8)	
	(Good	23.7	18.2	17.9	23.9	41.6	42.1)	
Adult	(Poor	24.7	19.3	17.1	21.6	41.8	40.9)	Imposed
	Average	24.2	18.7	17.5	22.8	41.7	41.5)	
	(Young.	21.9	18.1	19.7	22.9	41.6	41.2)	
Child	(Older	16.1	14.5	20.7	23.	36.3	37.6)	Spontan.
	Average	19.	16.3	20.2	23.	39.	39.4)	
	(Young.	27.9	20.4	13.1	21.4	41.	41.8)	
Child	(Older	24.7	19.4	17.1	21.8	41.7	41.2)	Imposed
	Average	26.3	19.9	15.1	21.6	41.4	41.5)	

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should inspect Table 3 of the Appendix. In Table 2 above, the Average of the two adult groups is computed as is also that of the two child groups in each case for ready compari-

son of child and adult behavior.

The differences which obtain between finger and arm movement results as well as between movement with spontaneous and imposed rhythm and also between adult and child groups is evident, but the question arises whether these differences are large enough to be significant as actual differences, or whether they might possibly be due to chance. Such a question can be answered statistically by the computation of a coefficient of reliability for each comparison made. The reliability of the differences between the group averages when used for comparative purposes was computed and is here tabulated in Table 3.

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Table 3

Coefficients of Reliability for Comparative Studies of Relationship in the Results of Table 2.

		Difference in Averages	Diff. divided by P.E. of diff. Coefficient of Reliability	Degree of Reliability
1. Comparison of Results for <u>Spontaneous</u> and <u>Imposed</u> Rhythm				
Adult Groups				
Rest	Finger	7.3	6.76	absolute
	Arm	5.8	7.4	absolute
Stroke	Finger	1.4	1.6	poor
	Arm	.9	1.07	low
Total	Finger	5.9	6.2	absolute
	Arm	6.7	6.6	absolute
Child Groups				
Rest	Finger	7.3	7.2	absolute
	Arm	3.6	4.7	high
Stroke	Finger	5.1	5.9	absolute
	Arm	1.4	1.8	fair
Total	Finger	2.4	1.95	good
	Arm	2.1	2.15	good

(Table 3 continued)

2. Comparison of Adult and Child Groups:

Using Spontaneous Rhythm

Rest	Finger	2.1	1.81	fair
	Arm	3.4	4.15	high
Stroke	Finger	1.3	1.5	poor
	Arm	1.1	1.1	very poor
Total	Finger	3.2	2.1	good
	Arm	4.6	3.3	high

Using Imposed Rhythm

Rest	Finger	2.1	2.3	good
	Arm	1.2	1.65	poor
Stroke	Finger	2.4	2.8	good
	Arm	1.2	1.7	poor
	Finger	.3	.97	very low
	Arm	0	0	none

3. Comparison of Finger and Arm Movements:

Adult Groups

Rest	Spontan.	4.	4.	high
	Imposed	5.5	6.2	absolute
Stroke	Spontan	3.	3.3	high
	Imposed	5.3	6.4	absolute
Total	Spontan	1.	.72	very low
	Imposed	.2	.905	very low

Child Groups

Rest	Spontan	2.7	2.7	good
	Imposed	6.4	8.4	absolute
Stroke	Spontan	2.8	3.1	good
	Imposed	6.5	8.9	absolute
Total	Spontan	.4	.26	very low
	Imposed	.1	.28	very low

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The reliability of a difference depends on several factors, the difference between the categories compared being the basic one. This difference is however of little significance except in relation to the mean variation of the

respective measures. And in the last place, the number of cases or subjects that have gone to make up this measure assist in determining how large a part chance may have played in the establishing of the difference.[1] Therefore it is necessary to take these factors into consideration in computing the coefficient of reliability.

This is done by finding first the Probable Error of the Mean for each group of measures to be compared. ($PE_m = \frac{.8453 \text{ A.D.}}{\sqrt{N}}$) The two P.E.'s are next related to discover what is the Probable Error of the difference between the two averages.

$$P.E._d = \sqrt{P.E._{m_1}^2 + P.E._{m_2}^2}$$

The actual difference (D) between the averages must necessarily be larger than the range of the Probable Error in order to be reliable. In other words, by the operation of pure chance the difference might amount to the same as the amount indicated by the Probable Error. Rugg States[1] that for dependable reliability it is requisite that the coefficient of reliability (the Difference divided by the P.E. of the difference) should be at least 1.9, so that the chances will be about 4 to 1 in favor of a real controlling distinction between the compared results.[2]

The tables of values for the Normal Probability Integral, as ordinarily given,[3] do not consider coefficients above 6 P.E. and any coefficient near or above this point may be

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1. Rugg, H.O., Statistical Methods Applied to Education. Houghton-Mifflin Co. 1917...p 232.
2. The method of reliability here employed is based upon Whipple, G.M., Manual of Mental and Physical Tests- Part One Warwick and York, 1914....pp.24-27.
3. See (Ibid) also Rugg (Op.cit.) Table IV Appendix,P.391

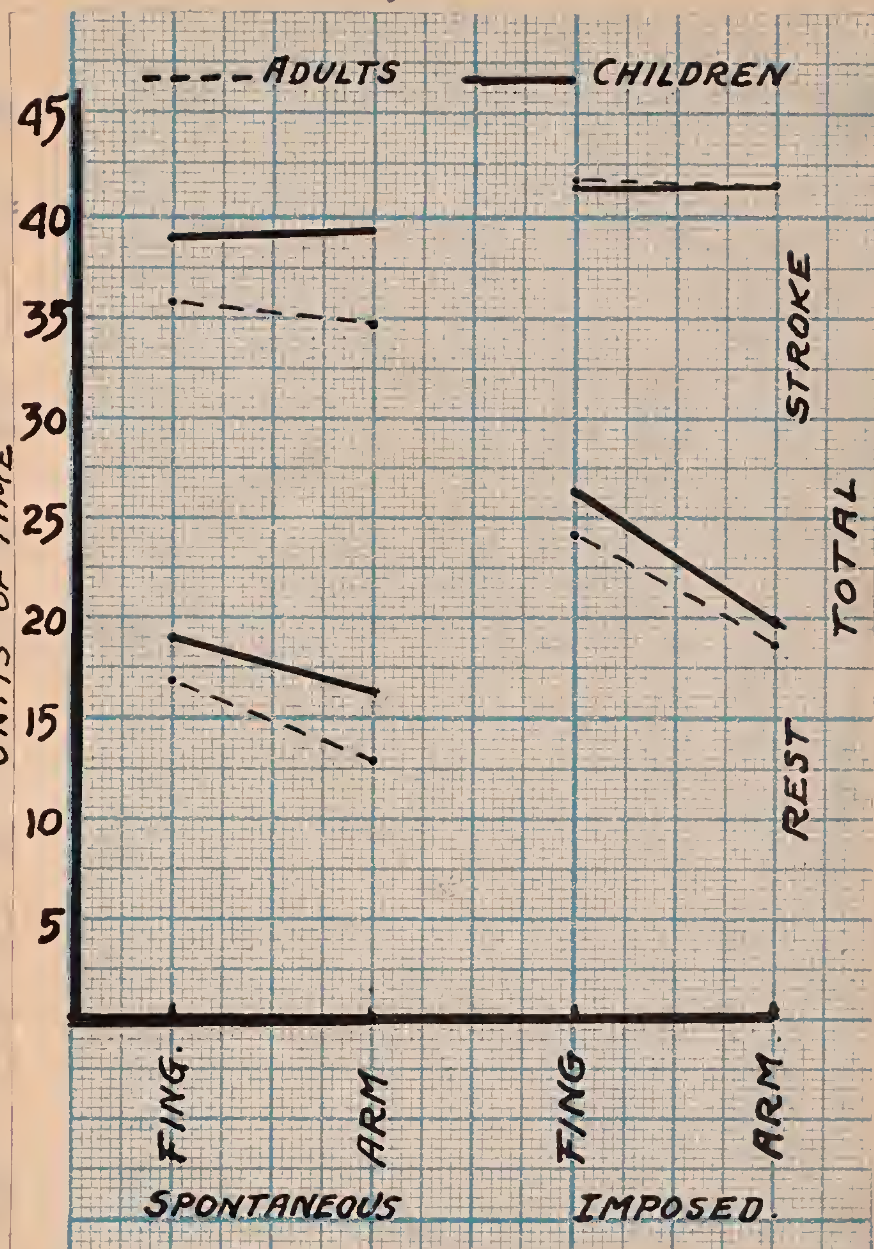
considered as absolutely reliable. Between the extreme ranges of coefficients, zero and absolute, we have noted very poor, poor or low, good, high and very high.

It is noteworthy that 10 of the 36 comparisons made show, in Table 3, a high degree of reliability that may be called absolute, 5 are high, 7 are definitely good, while two others are on the border of good, making altogether 24 which show reliable differences. Of the remainder, although differences will be noted, they will not be credited as proved without further data, and, in some cases at least, the fact of similarity may be as significant as any difference that might exist.

Analysis of Actual Time Measures:

The combined averages of the adult groups and the child groups, as noted in Table 2, are depicted graphically in Diagram 1 so as to show the comparison of the records made by the adult and child subjects, without regard to penmanship ability or age, under the various conditions of the experiment.

<u>The attempt to follow the rhythmic beat resulted in a perceptibly greater length of time being spent on the total stroke period</u> than was the case when the subject was allowed to set his own rhythm. This is an indication that the imposed beat was slightly slower than the natural rhythm of the average of the group, although it was as rapid as could be well followed, at least by the majority of subjects. This is true of both the adults and children, though the adults slowed down to a greater extent. It is also evident with both finger and armm movement.



Diag.1. Comparison of Child and Adult Groups as to the Amount of Time Spent at Rest, on the Stroke, and on the Total Movement under the Various Conditons of Finger and Arm Movement without and with Imposed Rhythm.

---------ADULTS ————— CHILDREN

One of the most persistent differences noted between the various groups, under the various conditons of the experiment is in the relative amount of time of the total period that is given to rest. A summary of Table 4 (Appendix)

here given in Table 4, so that all the group records may be compared as to their behavior with finger and arm movement both without and with imposed rhythm.

Table 4

Average Percentage of Time Spent at Rest

		Spontaneous		Imposed	
		Finger	Arm	Finger	Arm
Adult	Better Writers	46	37.1	54.4	45.6
	Poorer Writers	47.1	39.	58.7	43.1
Average		46.5	38.	56.5	44.3
Child	Younger	53.8	44.2	68.4	49.7
	Older	43.	38.7	56.5	47.2
Average		48.4	41.4	62.4	48.4

For purposes of comparing the adult and child averages above, the following Table of Reliability (Table 5) is here presented. The method of determining the coefficient of reliability is the same as that used before (Table 3).

Table 5

Reliability of Differences in the Proportion of Time Spent at Rest.

		Difference	Ratio of Reliability	Degree of Reliability
1. Comparison of Results for Spontaneous and Imposed Rhythm:				
Adults	Finger	10	4.6	very high
	Arm	6.3	3.5	high
Child	Finger	14	7	absolute
	Arm	7	4.8	very high
2. Comparison of Adult and Child Groups:				
Spon.	Finger	1.9	.92	low
	Arm	3.4	2.3	good

Imposed	Finger	5.9	2.8	good
	Arm	4.1	2.3	good

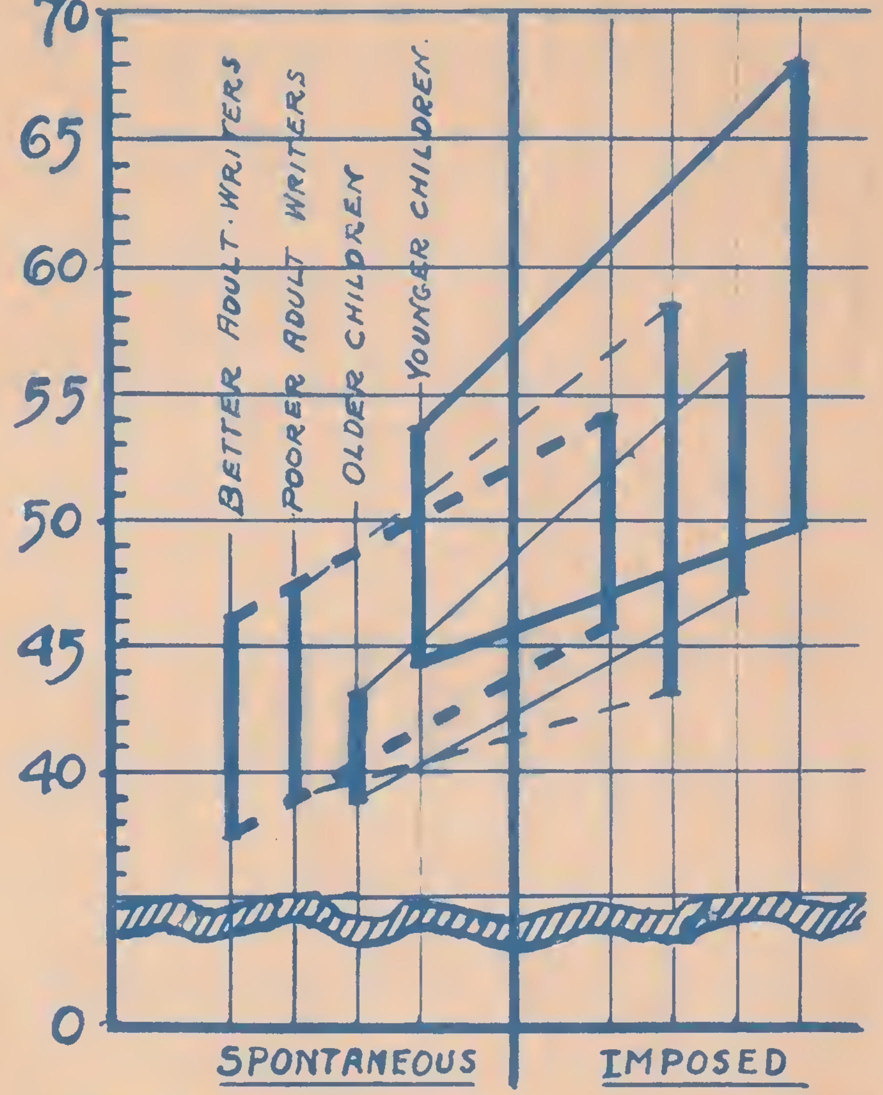
3. Comparison of Results for Finger and Arm Movement.

Adults	Spontan.	8.5	4.6	very high
	Imposed	12.2	5.7	absolute
Children	Spontan.	7.	4.1	high
	Imposed	14.	7.9	absolute

The differences show themselves to be reliable in nearly all cases. The one exception is due to the fact that the child average considered is made up of two widely different measures; one much higher than the adult, the other lower so that the factor of age development in the child group interferes with the comparative value, which would obtain if only the younger children were considered.

The date of the above Tables (4 and 5) show quite clearly that imposed rhythm causes the subject to quicken his stroke and spend more time proportionately at rest than is the case with spontaneous rhythm. In case the conclusion noted (pp. 16-17) is taken as conclusive, the lengthening of the period of rest preceding the stroke would tend to diminish the accuracy of the stroke, hence the imposed rhythm would operate to a disadvantage in the case of the majority of subjects.

The finger appears quicker in movement than the arm, the latter always limiting itself to a shorter rest period than the finger. The arm is not as facile an agent as the finger in executing a movement on account of its inertia, hence the subject is forced to make the accommodation whereby more time



DIAG. 2.– PER CENT OF TIME SPENT AT REST BY THE VARIOUS GROUPS USING FINGER AND ARM MOVEMENT WITHOUT AND WITH IMPOSED RHYTHM.

LEGEND
- YOUNGER CHILDREN.
- OLDER CHILDREN
- ADULT – POOR WRITERS.
- ADULT – GOOD WRITERS

UPPER LIMITS OF COLUMNS = RECORD WITH FINGER MOVEMENT.

LOWER LIMITS OF COLUMNS = RECORD WITH ARM MOVEMENT.

is provided for the movement proper than when the finger movement is used. Age does not seem to be a significant factor in relation to this adjustment since child and adult groups show quite similar behavior. It might be inferred that the use of the arm would give greater accuracy of movement than the finger, again referring to the conclusion above noted (pp 16,23) but it must be kept in mind that that conclusion is not based upon comparison of different motor elements, but upon different conditions under which the same one operates.

The differentiated groups of Better Adult Writers, Poorer Adult Writers, Younger Children and Older Children are compared in Diagram 2, as to their respective average percentage of time spent at rest under the various conditions. In the case of every group imposed rhythm results in a greater amount of relative time being given to rest, both with the use of finger and arm movement. Table 4 of the Appendix shows this to be true,

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Diagram 2. Per Cent of Time at Rest

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not merely as a quantitative average, but also as characteristic of the majority of the subjects, all of the children and all but four of the adults being thus affected. Except in the case of better adult writers the difference is moremarked in finger than in arm movement.

The younger children give a longer proportionate time to rest than do any of the other groups, and this maybe fairly regarded as symptomatic of their greater inaccuracy of movement. The older child group is not so clearly differentiated from the

adult groups, in fact the record is generally smaller than that of the group of poor adult writers, and compares quite favorably with the record of the better adult writers, even being less with the use of finger movement in auto-rhythmitization.

It is probably significant that the quadrilateral figure representing the records of the better adult writers is so nearly a perfect parallellogram showing that the finger and arm are equally affected by the imposition of rhythm. The other groups show no such a uniformity of difference, but on the contrary show that the finger and arm are unequally affected, the former showing a much greater difference with imposed rhythm than the latter. The better adult writers seem to have a more perfect control of the motor factors of both arm and finger and have no difficulty in making the adjustment with either to imposed rhythm. The group of poorer adult writers presents a record which is almost identical in form with that with that of the younger children, although it is placed lower in the scale, and this type of record may be symptomatic of the lack of motor control which is known to exist in these two groups. The older children show a modification of finger movement similar to that of the younger children, but the change in the results for arm movement is more like that of the better adult writers. This may be due to the fact that this group has not yet attained fixed control of the finger movement to the degree that arm movement has been habituated.

The correlation of age with the per cent of time spent at rest among the child groups has been worked out for the differ- ent conditions of finger and arm movement, without and with the

imposition of the rhythmic guide. The computation of the coefficient of correlation for the four cases is presented in Table 5 of the Appendix, the Pearson method by grades being made use of as the one best adapted to indicate readily though roughly any prominent relationship that might exist. The coefficients there discovered are as follows:

Coefficients of Correlation between Age and PerCent of Time Spent at Rest

	Spontaneous	Imposed Rhythm
Finger Movement	(A) $-.641 \pm .08$	(C) $-.507 \pm .104$
Arm Movement	(B) $-.458 \pm .109$	(D) $-.01$

It is noteworthy that the coefficients in Parts A,B, and C, although not great, are large enough to indicate the presence of a marked degree of negative correlation in each case. But in Part D there is no evidence of any correlation between the two factors.

The findings of the correlation computation agree consistently with those already noted (p. 43) in which group averages only were considered. As children grow older they tend to give less proportionate time to the rest period at the initiation of the stroke when acting without a rhythmic guide, and also when using finger movement with imposed rhythm, but when attempting to follow the imposed rhythm while using arm movement this relationship does not hold. Arm movement habits have been formed which must be readjusted when an imposed rhythm is followed. This introduces an element of uncertainty into the subject's behavior which manifests itself

by an increase of the rest period. Finger habits have not been formed in the majority of cases which cause difficulty in taking on an imposed rhythm, hence the adjustment is quite readily made.

Analysis of Derived Measures of Variability:

In Table 4 of the Appendix is given a summary of findings with regard to the variation of the single measures of each subject from the average duration of his stroke elements. This Table is composed in a similar way to that of Table 3 of the Appendix so as to make ready comparison of finger and arm movement results under conditions of spontaneous and imposed rhythm. In addition, the percentage of time spent at rest is computed for each subject, and also the percentage of deviation of each subject from the imposed beat is noted in Parts B and D. In Part C the age of the child subjects is added as a matter of reference. In Table 6 the means for the performance of the various groups are presented, distinction being made between the better and poorer adult writers, as well as the younger and older children. Only the matter of variation is here dealt with. See pp. 43 ff and 60 ff, for a presentation of summary tables for the remainder of the data.

Table 6

Average Coefficients of Variation from Temporal Uniformity

Group		Rest		Stroke		Total		
		Fing.	Arm	Fing.	Arm	Fing.	Arm	
Adult	Good	13.7	18.2	10.5	8.7	6.8	6.4)	
	Poor	15.4	13.6	11.	7.9	6.3	6.5)	Spontaneous.
Average		14.5	15.9	10.7	8.3	6.5	6.4)	

Adult	Good	14.3	16.8	10.8	9.7	8.	7.1)	
	Poor	16.1	17.3	13.	11.	8.4	7.8)	Imposed
Average		15.2	17.2	11.9	10.3	8.2	7.4)	
Child	Young	21.8	20.	24.1	14.4	13.7	8.8)	
	Older	16.3	15.8	13.	9.4	14.4	7.9)	Spontaneous
Average		19.	17.9	18.5	11.9	14.	8.3)	
Child	Young	18.6	22.9	20.5	17.2	11.8	12.3)	
	Older	15.8	21.75	15.5	14.9	8.8	9.7)	Imposed
Average		17.2	22.3	18.	16.	10.3	11.)	

The reliability of the averages of Table 6 for comparative purposes is computed and presented in Table 7, the same method of computation being used as in Table 3 (pp. Only the combined averages for all adults, and all Children are here treated because only 12 cases provide a manifestly inadequate number for intensive statistical treatment.

Table 7

Coefficients of Reliability for Comparative Studies of Relationship in the Results of Table 4.

		Difference of Averages	Coefficient of Reliability	Degree of Reliability
1. Comparison of Results for Spontaneous and Imposed Rhythm				
Adult Groups:				
Rest	Finger	.7	.61	very low
	Arm	1.1	.70	very low
Stroke	Finger	1.2	1.4	poor
	Arm	2.	2.7	good
Total	Finger	1.7	2.75	good
	Arm	1.	2.06	good
Child Groups:				
Rest	Finger	1.8	1.51	poor
	Arm	4.4	2.8	good
Stroke	Finger	.5	.32	very low
	Arm	4.1	4.1	high
Total	Finger	3.7	4.	high
	Arm	2.7	3.8	high

2. Comparison of Adult and Child Groups:

Using Spontaneous Rhythm:

Rest	Finger	4.5	3.7	high
	Arm	2.	1.46	poor
Stroke	Finger	7.8	5.8	absolute
	Arm	3.6	5.3	very high
Total	Finger	7.5	8.4	absolute
	Arm	1.9	4.13	high

Using Imposed Rhythm:

Rest	Finger	2.	1.77	fair
	Arm	5.3	3.2	high
Stroke	Finger	6.1	5.35	very high
	Arm	5.7	5.5	very high
Total	Finger	2.1	3.17	high
	Arm	3.6	4.9	very high

3. Comparison of Finger and Arm Movements:

Adult Groups:

Rest	Spontan	1.4	1.13	low
	Imposed	1.8	1.3	low
Stroke	Spontan	2.4	3.6	high
	Imposed	1.6	1.74	fair
Total	Spontan	.1	.2	none
	Imposed	.8	1.27	low

Child Groups:

Rest	Spontan	1.1	.81	very low
	Imposed	5.1	3.6	high
Stroke	Spontan	6.6	4.85	very high
	Imposed	2.	1.6	poor
Total	Spontan	5.7	6.5	absolute
	Imposed	.7	.92	low

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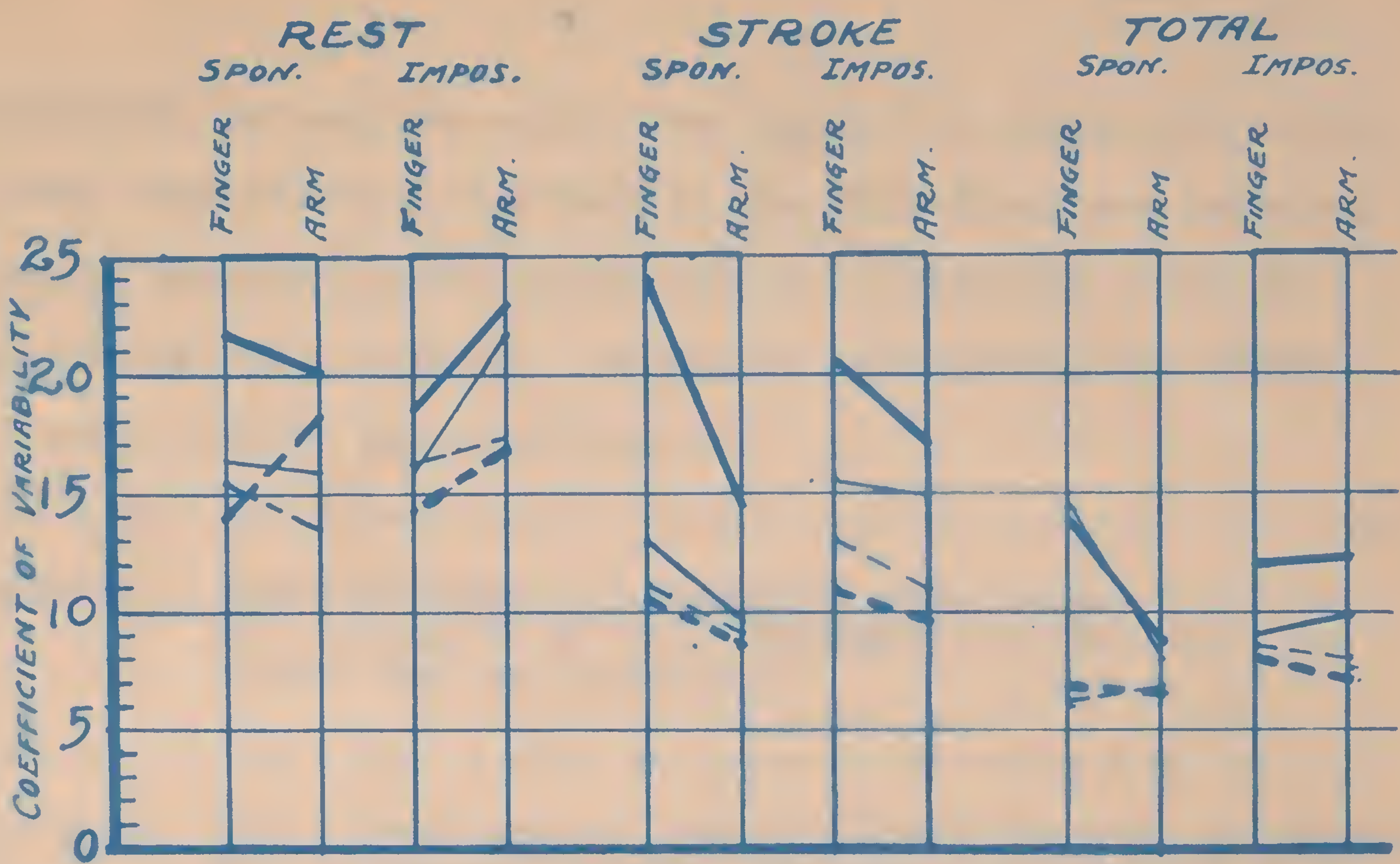
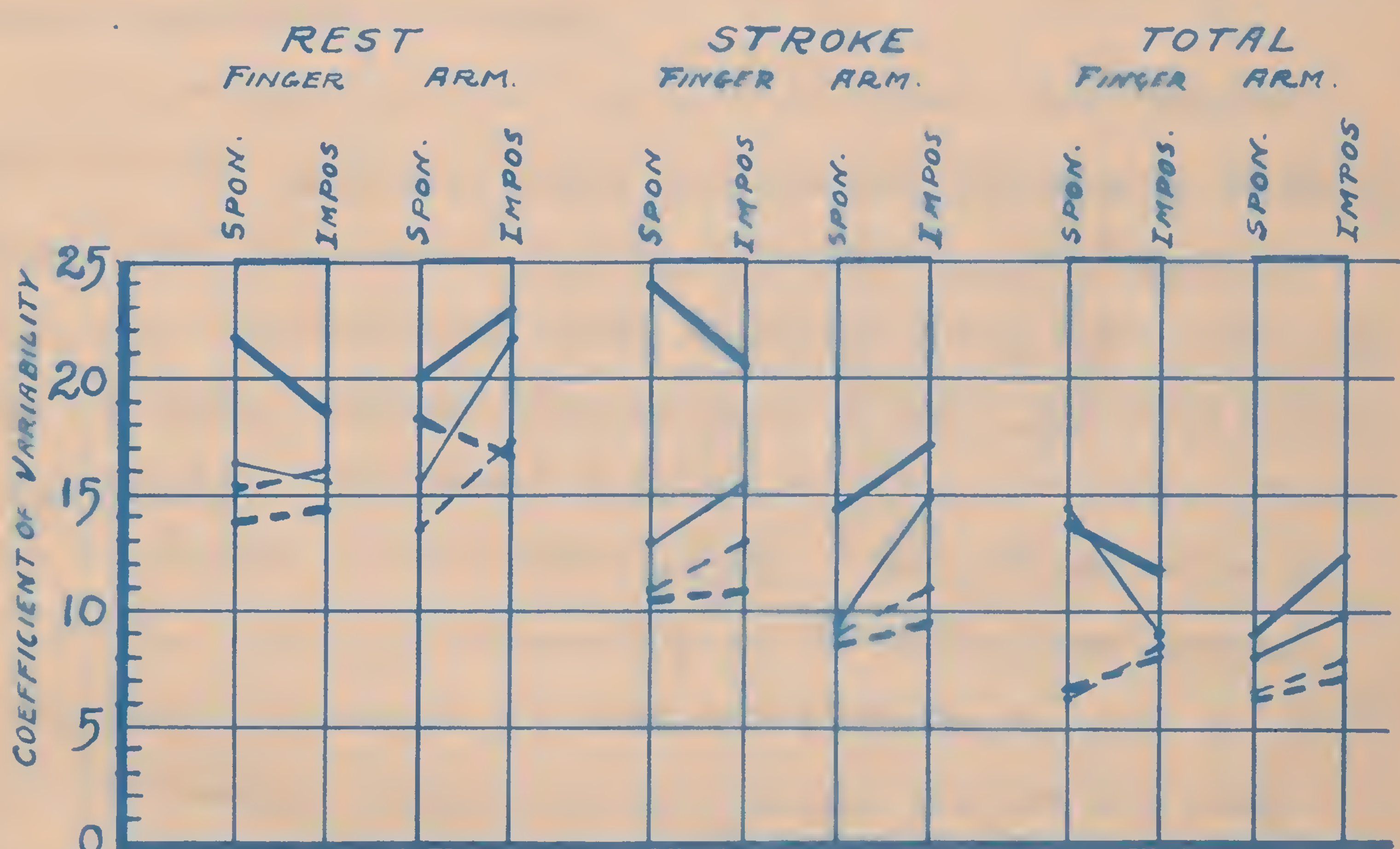
The findings shown in the above table will be referred to as occasion demands in the succeeding discussion.

In Diagram 2 the average measures of Table 6 are presented



DIAG. 3. GROUP AVERAGES OF VARIATION FROM TEMPORAL UNIFORMITY Arranged so as to Show Comparison of Records for Finger and Arm Movement.



DIAG. 4.- GROUP AVERAGES OF VARIATION FROM TEMPORAL UNIFORMITY. Same as Diag. 3. but arranged so as to show Comparison of Records for Spontaneous Movement and Movement following Imposed Rhythm.

COMMON LEGEND

- YOUNGER CHILDREN
- OLDER CHILDREN
- ADULTS - POOR WRITERS
- ADULTS - GOOD WRITERS.

graphically in much the same order as in the table with a view to easy comparison of the records for finger and arm movement while in Diagram 3 they are placed in a different order from that of the table with the purpose of emphasizing the effect of imposed rhythm upon behavior.

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Diagram 3 Group Averages of Variation from Temporal Uniformity. Arranged to Show Comparison of Records with Finger and Arm Movement.

- -

Diagram 4 Group Averages of Variation from Temporal Uniformity. Arranged to Show Comparison of Records with Spontaneous and Imposed Rhythm.

- -

General Comparison of Groups:

It is noticeable from the data of Table 6 and Diagrams 3 and 4, that the variationof the younger children is generally greater than that of any of the other groups, and that the adults show the least variation in nearly every case, with the group of better writers maintaining a slightly superior record of regularity. The group of older children exhibits a record which fluctuates between the records of the younger children and adults. The high reliability of the difference between the children and adults has been noted (Table 7, p.49). The clear delineation of the two child groups and the two adult groups and the consistent results of the whole table indicate still further the reliability of the measures.

Relation of Stroke Elements:

The comparatively high per cent of variation which occurs

in the rest and stroke periods, especially the former, and the lower deviation in the total period would seem to indicate a general reaction to the total period as a unit that is not evident in either the period of rest or the time given to the movement proper. The initial adjustment in the rest is experienced as an essential element in the total stroke equally with the motion itself. The rest and stroke periods tend to be more variable than the total period, but comparison of the rest periods with successive stroke periods shows that the lengthening of either stroke or rest periods beyond the average of a given subject tends to be compensated for by a corresponding shortening of the rest or stroke period respectively, and vice versa.

Comparison of Finger and Arm Movement:

The contrast between the amounts of variation gotten with the use of finger and arm movement respectively is in some cases quite striking, but on the whole the differences are not highly reliable.(p.50.). We will first generally note the trend of measures as evidenced in the table, then discuss more in detail those which appear most reliable. (See Diagram 3).

The use of the arm movement seems in general to favor the time rhythm when the child initiates his own rhythm. This is very notable in the case of the child groups in all stroke elements. The child has evidently not been able to bring his finger movement under such regular control, as he has his arm movement. The arm is a more massive instrument and its inertia causes it to be more rhythmically moved than the fingers which

are lighter and more subject to variable controls.

Possibly practise may have had something to do with this characteristic, since most of the children received training in arm movement exercises in the public schools. The adults do not show any reliable demarkation between the two types of movement in these results.

The attempt by children, to follow the imposed rhythm seems to affect the temporal regularity of the arm movement unfavorably to a greater extent than is the case with finger movement. The arm mass interferes with proper readjustment to an objective stimulus. The adults, however, seem to have attained such control as to give the arm movement a slight advantage, under the same conditions, except in the period of rest.

Comparison of Spontaneous and Imposed Rhythms:

The effect of the rhythmic stimulation is clearly noticeable (Diagram 4). In general, for the adults, the amount of variation is markedly greater in both finger and arm movement when the rhythm is followed. The only exception occurs in the case of the better writers during the rest period with the use of the arm movement, when a smaller variation is evident, the record for spontaneous movement being comparatively high. The better writers, for the most part, show less modification of behavior when following the rhythm than do the other groups.

The younger children exhibit a tendency quite different from that of the adults when following the rhythm. Where finger movement is used the variation is smaller with imposed rhythm, while the variation is greater with arm movement. The

older children show the same tendency except in the movement proper, in which their record is very much like that of the adults in character. Doubtless this fact is closely related to types of habituation. It may be that the child has already fixed quite definite habits of temporal regularity with the use of the arm and any attempt to modify this type of performance in accordance with an artificial objective naturally meets with definite interference. On the other hand, the child does not seem to have attained any temporal rhythmic control of the fingers, hence the adjustment is quite ready in taking on an imposed rhythm. Again, as has already been suggested, the underlying factor may be the physiological adaptability of the arm for rhythmic movement as compared with the finger, in which case habituation is the secondary and derived element. However, that may be, it is significant that the adults find it more difficult to adapt themselves to a rhythm foreign to their habits than do the children, so that the imposed rhythm actually decreases their temporal regularity.

The individual records of Table 4 of the Appendix show that only one of the 12 subjects under 11-1/2 years of age exhibits a smaller variation in the total period when using arm movement in following the rhythm. Those child subjects over this age either show a smaller variation or a proportionately smaller degree of positive difference than the younger subjects. The majority of the younger subjects manifest a corresponding tendency to smaller variation when following the rhythmic beat with the finger movement.

Comparison of Groups as to Range of Variation:

Study of the comparative length of range between the lowest record of any individual in the respective group and the highest individual record made in the particular element shows that in general the range of most of the groups is compacted in the total period as well as placed lower in the scale, compared with the other periods.

The total spread for each group is summarized in the following Table (Table 8) by stroke units, with a view to

Table 8

Range of Variation

			Better Adult	Poorer Adult	Old Child	Young Child
Rest	Finger	Spon.	14	18.6	13.8	30.6
		Impos.	14	33.4	17.4	20.2
	Arm	Spon.	21.4	18.8	24.8	24.1
		Impos.	21.3	30.1	20.8	26.
Stroke	Finger	Spon.	9.	15.9	14.8	36.
		Impos.	15.3	15.4	17.4	34.
	Arm	Spon.	9.4	13.	6.9	22.2
		Impos.	16.	15.4	16.5	21.4
Total	Finger	Spon.	9.7	8.1	16.6	20.1
		Impos.	9.5	21.3	7.6	13.5
	Arm	Spon.	7.4	6.4	5.6	11.7
		Impos.	8.9	10.	17.7	12.7
Summation			155.9	204.4	178.9	273.1

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noting the comparison of the groups as to their tendency to a wide range of variation. According to this table it is seen that the younger child group furnishes a total of spreads nearly twice that of the better adult writers while the older

children have a range which is about an average of the two adult groups. On the basis of this evidence one must recognize the tendency of the younger and poorer writers toward wider ranges of variation.

The range of variation for the group of better writers is relatively less than for any of the other groups, though it is not in every case smaller, or placed lower in the scale. In no case does the record for younger children show the lowest measure or the smallest range; in fact the extremely wide range which occurs in most cases with this group is most significant. Some members of the group of poorer adult writers exhibit as large a variation as any of the younger children but this occurs only in the results gotten under conditions of imposed rhythm. The older children show throughout a record slightly inferior to that of the better adult writers in point of both spread and lower limits of variation, and are in many cases superior to the group of poorer adult writers in these respects.

The imposition of rhythm tends to increase the range and heighten the lower limit of all groups in the total period with the use of arm movement. The same thing is true of the stroke period, but in the rest period only the poorer writers and the younger children show a greater range under these conditions. When finger movement is used the attempt to follow the rhythm results in a smaller range of variation for the children, at least for the total period, but all groups show greater range of variation in the stroke period with imposed rhythm than without it.

Arm movement tends generally to give less range of varia-

tion among all groups than does finger movement when the rhythmic movement is undirected. But when rhythm is imposed the poorer writers alone show a greater range in the total period with finger movement.

In general the range of variation as shown in the records harmonize with the averages before noted. It is noteworthy that the arm is again, by this method, indicated as more susceptible to natural temporal regularity, but not as apt as the finger in taking on an imposed rhythm. It is possible that some of the poorer adult writers were so thoroughly habituated in the rhythmic movement of the fingers that the attempt to modify their finger movement in accordance with the rhythmic stimulus met with definite interference.

A study of the place rank of each individual of the 48 subjects in comparison with the others was made. (~~See Appendix, Table V.~~) It was found that about 34% of the total number which have variations greater than the median is equally divided between the two adult groups, while 40% of this number are composed of younger children, and the remainder, or 26% are made up of the older children. There is, therefore, shown to be a distinct correlation between age and decrease in variation. There is no evidence however that the group of better writers among the adults have a better average rank than the poorer writers.

It is noteworthy that some subjects receive a high rank in finger movement but low in arm movement, or vice versa, while others tend to receive about the same rank in each under the same conditions. In the same way, imposed rhythm may

operate so as to effectually change a person's rank in either finger or arm movement or both, or it may not affect either appreciably. To what extent these factors are characteristic of any person's behavior could only be told by an intensive analysis of individual cases through many repetitions of well controlled experimentation.

A detailed study of the place rank of the subjects reveals a marked overlapping of rhythmic abilities of children and adults. The children differ quite markedly from the adults when using finger movement while initiating their own rhythm, but show a trend quite similar to that of the adults when using arm movement. The use of the imposed rhythm tends to bring the two groups toward agreement when using finger movement by affecting the adults unfavorably and the children favorably, but when the arm movement is used with imposed rhythm, the children are unfavorably affected to a more marked degree than the adults, hence tend to deviate to a greater extent from the characteristic adult trend. These facts again substantiate those already noted (pp. 51-4) and tend to confirm the hypothesis that the finger rhythm is later in being acquired than the arm rhythm, and further, that the imposition of rhythm is of no immediate help to rhythmitization when such natural rhythmic habits have once been formed, in either finger or arm movement.

Many members of each group do not follow the imposed rhythm with as good an effect on temporal regularity as do others, in fact, show themselves adversely affected by it. It is possible

that this fact may be due to the newness of the exercise, and might be overcome by a longer period of drill, but inasmuch as all were subject to the same conditions, the facts portrayed indicate marked individual difference in the readiness with which a rhythmic pace can be imitated.

The records of the adult subjects were analyzed and compared for evidence of correlation between the variation in the time spent at rest and the per cent of the total stroke spent at rest. The rank tabulation and computation are shown in Table 6 of the Appendix by which the following coefficients of correlation were found, the Pearson method by grades being used.

Table 10

Coefficient of Correlation between Variation in Rest Period and Per Cent of Total Period Spent at Rest

	Spontaneous	Imposed
Finger Movement	-.591 ±.085	-.402 ±.115
Arm Movement	-.573 ±.092	-.041

Only the record made with arm movement under conditions of imposed rhythm fails to show any correlation, while the ratios for the Parts A, B, and C show marked evidence of negative correlation between the two elements.

Reducing the amount of time spent on rest is here accompanied with an increase of variability in the time given to the rest period, both when using finger and arm movement with spontaneous rhythm, also when following an imposed rhythm with finger movement but there is no evidence of such a relationship when following the rhythm with the arm movement. It is natural

that the shorter the period within certain limits the less accurately its length could be judged and reproduced, but just what significance this fact would have to the writing process is uncertain. It is however noteworthy that the imposed rhythm introduces such a disturbance into the relations which normally obtain, especially when the arm movement is being used.

Ability to Follow the Rhythmic Guide:

It has been noted (p. 48) that the individual deviations from the metronome beat have been computed and show in Table 4 of the Appendix. The method by which these measures were computed and their significance was presented previously (p. 32). A summary table follows which shows the percentage of deviation of each group, on the average, from the incidence of the beat.

Table 10
(Percentage of Deviation from the Incidence of the Beat)

		Finger	Arm
Adults	Better Writers	11.9	14.2
	Poorer Writers	16.3	24.6
	Average	13.9	18.9
Child	Young Children	23.1	22.9
	Older Children	12.6	17.1
	Average	17.8	20.

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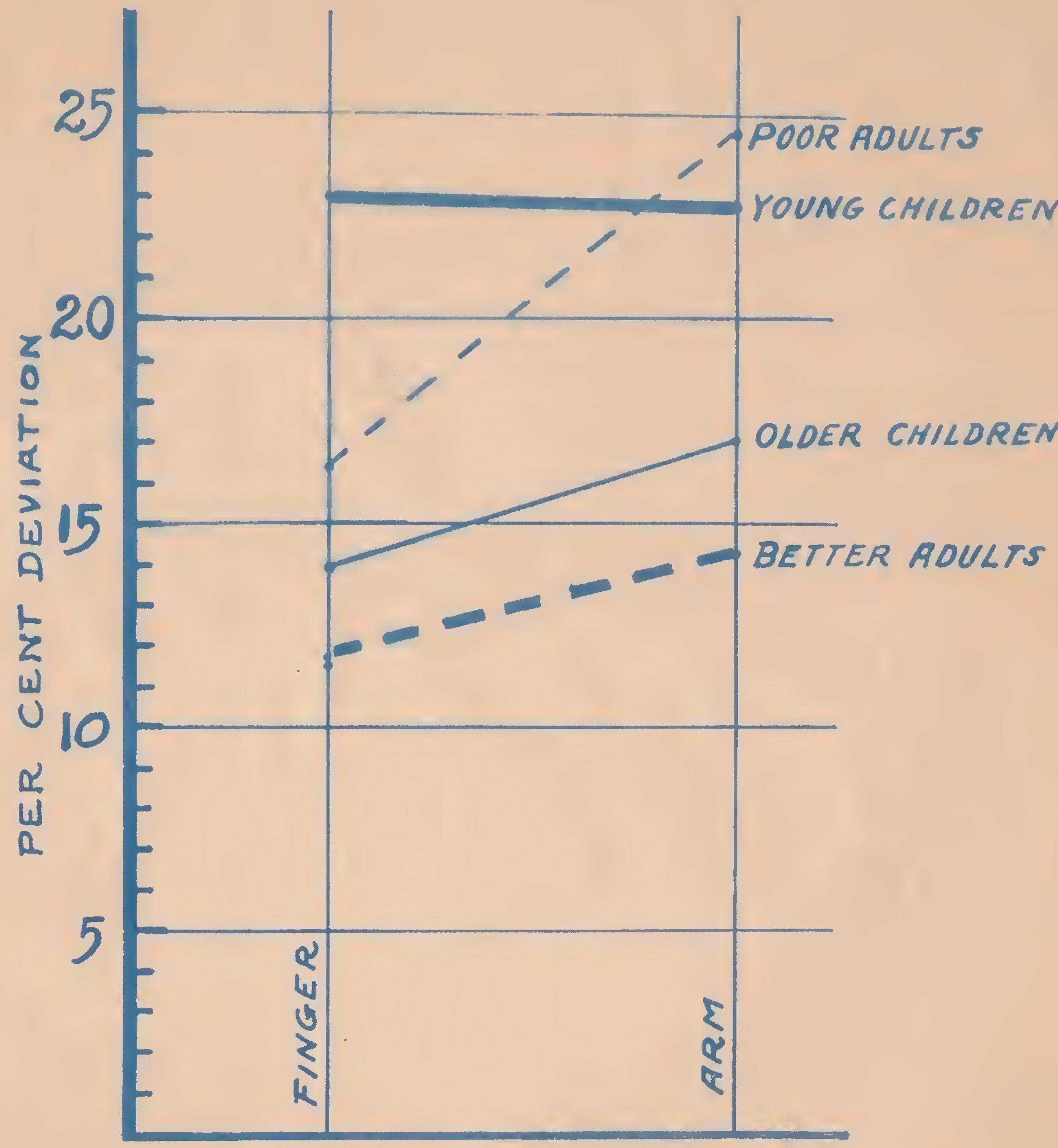
Comparison of the various groups as to their behavior in this respect is aided by Diagram 5., which represents the data of the above tabulation graphically. Except in the case of the younger children who remain quite constant in their record, all groups tend to deviate farther from the beat with the use of the arm movement than with the use of finger movement, the



Diag. 5 Comparison of Child and Adult Groups as to their Average Per Cent Deviation from the Incidence of the Beat in following an Imposed Rhythm.

group of poorer adult writers differing most markedly of all. The better writers of the adult groups show clearly their superiority in respect to smaller deviation in both finger and arm movement while the older child group has a record not

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Diagram 5. Comparison of Child andAdult Groups as to their Average Per Cent Deviation from Incidence of the Beat in following an Imposed Rhythm.

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greatly different from this superior group. The poorer adult writers, though showing appreciably less deviation than the younger children when using finger movement exhibit greater deviation than the younger children when using arm movement. Here we find then that the better writers and the older children, who for the most part have already developed good penmanship habits, are able to adapt themselves to the rhythmic beat with greater accuracy than the poor adult writers or younger children.

A survey of the individual records, stroke by stroke, shows that the greater deviation of the younger child and poorer adult writers is due to extreme lagging behind the beat. Although the other two groups show a tendency to lag at times, the deviation is not so large and is accumulated by small positive and negative deviations, in which the subject gradually accelerates to a point where he is in advance of the beat, then gradually retards to a lower limit of lagging, then repeats the process. We have already noted (P.12) Dunlap's findings in which he discovered a tendency to drift away from the imposed beat, then to drift back again. There are more among the older

child group than in any other group that tend to show deviation due to accelerating their movement beyond the rate of the imposed rhythm. They have formed rhythmic habits faster than the beat imposed, and tend constantly to give way to them but are restrained by the beat from doing so.

DISCUSSION AND CONCLUSIONS

It will be valuable to note in summary the findings of the preceding experiment which apply to the field of handwriting, to indicate the ways in which they may be of significance, and to compare them briefly with a view to discovering solutions to problems, as well as to suggest other problems which may be involved.

The results show a clear differentiation, in most cases, between the various groups selected as subjects. It may be possible that some significant elements of the data have been overlooked, and that real differences exist even where the reliability of differences as found in this experiment has been low. The inference is justified that the reliable differences found are a concomitant, and probably a resultant, of the known distinctive differences in the subjects.

Of the four groups only one is made up of matured writers who exhibit a generally high quality of penmanship. But most of the older children are good writers, being well trained in the public schools in a standard system of penmanship instruction. In only two of this group is there found any marked lack of coordination. The adults who compose the group of poorer

writers and the younger children are definitely poor penmen, showing either a noticeable lack of coordination, or deformation of letter forms, or both in most cases.

The good and poor writers are not clearly distinct in their degree of variation from an average duration,although the superior adult group ranks as having slightly the lowest degreeof variation. The older child group, which is undoubtedly superior in penmanship ability to the poorer adult writers, shows itself of lower rank in the sense of exhibiting generally a less rhythmical behavior. It is true that the younger child group is differentiated as to variation from the other groups, but this fact would harmonize with the supposition that the rhythmic ability is not primarily a correlate of good penmanship, at least in the simple temporal sense in which rhythm is here used, but rather an independent factor which is a matter of habituation, and which is attained more fully with age maturity.

Some children among the younger group show unusual rhythmic ability. For example, the child aged 10 years 8 months (Table 4-Appendix) is more rhythmical on the average than the group of better writers as a whole. It is notable that, at about the age of 11 years, there seems to be a more numerous grouping of those who show more rhythmical ability than is the case among younger subjects. This fact agrees with that already noted by Freeman and Nutt (p. 14) also Sears (p. 13).

The most significant differences between the good and poor writers seems to lie in certain other elements especially.

These are (1) readiness of adaptation to an imposed rhythm with both finger and arm movement, and (2) the accuracy with which the imposed beat is followed.

With regard to the first point it was noted (p. 46) that all groups are affected in the increase of the proportion of time spent at rest by the imposition of rhythm but that the better writers, in contrast to the other groups, were influenced to an equal degree when using finger and arm movement. The record of the group of poorer adult writers was quite child-like in character, not only showing a greater tendency toward increase of duration of rest period when imposed rhythm was used than was true of the better writers, but also being more greatly influenced when using finger movement than when using arm movement.

In the second element indicated it is again noteworthy that the two poor penmanship groups approximate. Both deviate to a greater extent than the good writers from the incidence of the beat, especially when arm movement is used. There seems to be a lack of ready adaptability in these groups which makes it difficult for them to follow any set rhythm. There may be totally different reasons in the case of the two groups for their common lack of adaptation. It is possible that the difficulty in the case of the children is chiefly the lack of motor control which is necessary to effect synchronization, while the elder group may have become so habituated in their particular used unit of rhythm that they find it difficult to change.

But whatever may be the reason, the better writers are more nearly able to follow the imposed beat accurately with both finger and arm movement and this may be ascribed to the superior motor control. To what an extent practise in following such a beat might prove instrumental in building up motor control, and hence improving penmanship ability, is problematical. It is possible that the lack of adaptability in this respect is irremediable. It is also possible that this fact is merely a symptom of an underlying difficulty which must first receive direct attention and improvement.

The comparison of the behavior of the subjects with finger and arm movement is timely in its relationship to penmanship instruction. In the case of all groups where arm movement was used, the imposition of a rhythm results in a greater degree of variation than when the movement was spontaneous. The same thing is true of the adults also when finger movement is used, but, in this case, the children show a markedly greater degree of rhythm. <u>In other words the setting of an artificial rhythm as a guide is, in the case of adults, a hindrance to rhythmic functioning; also for children when making use of arm movement, though the latter are aided by it when using finger movement.</u>

This is probably due, as has been pointed out (pp. 53-4), to the fact that adults have fixed rhythmic controls with both finger and arm movement, and that children early manifest such rhythmic abilities in the use of arm movement, though quite tardy in the acquisition of rhythmic abilities with finger movement. This explanation is not in full harmony with the

findings of Nutt ("Rhythm in Handwriting"..p. 436) who notes the slow development of arm movement: but the cases are quite different. In connection with this experiment the kinaesthetic impulse to rhythm is much more readily appreciated in gross bodily movements than in the finer adjustments, in which a special act of willmust operate so as to inhibit the gross movements and gradually select the small motor agents. The child's rhythmic ability is probably not so much an acquired habit of facile control such as occurs in the adult, as it is a fundamental physiological tendency. A further contributing factor may be the essentially distinctive character of the arm considered as a lever or pendulum, possessing quite different elements of mass and inertia than the finger, and consequently more disposed to rhythmical swinging movement, yet more difficult in ready adaptation.

It is noteworthy that the group of older children, who have been trained well in free arm movement, show little differentiation from the younger children in the degree of variation in the total period while using finger movement, and that both are greatly aided in the attainment of rhythm with the use of the fingers, by the imposition of rhythmic stimulus. This fact would suggest that, if the acquirement of rhythmic control with both finger and arm movement is desirable, children should be drilled with finger movement as well as arm movement that such control might be gained as early as possible.

It is possible and indeed probable that rhythmic control in the sense of ability to attain a natural temporal regularity, is probably of no great significance for good penmanship. But

the same finger-arm relationship holds true when the effect of imposed rhythm upon the amount of time spent at rest is considered. The poorer writers of both the child and adult groups, also to a smaller extent, the older child group, show a more appreciable difference from the record of the natural rhythm, when using finger movement than when using arm movement. This indicates a lack of habituation in the finger control as compared with arm control, and the consequent tendency to be more greatly influenced by the distractive factor of the artificial rhythm when using the finger than when using the arm. The group of better writers, on the other hand, appear to have control of both finger and arm movement ot an equal degree, inasmuch as both are equally influenced by the beat.

The extent to which the use of imposed rhythm with arm movement broke up the relations which normally obtain between groups (pp. 59-61) is a further indication of the fact that the arm does not yield as readily to the imposed beat. In general the use of arm movement tends to a more definite temporal rhythmic control. Only when the rhythm is artificially set does the rhythmic control by the arm suffer a loss, especially noticeable in the case of children.

The accuracy with which the imposed beat is followed by the various groups (p. 61) reveals a clear differentiation between the results for finger and arm movement. In all cases, except that of the younger children, the deviation is greater with arm movement. The younger children exhibit a lack of

ready control of the finger movement especially and the poorer adult writers in addition show a marked deficiency in arm control sufficient to follow the imposed rhythm accurately. Hence, from the point of view of these facts one is led again to the hypothesis that either the arm movement habits or the essential inertia of the arm movement affects the subjects unfavorably in their taking on an imposed rhythm, as compared with the finger. The younger children here also show characteristic deficiency of control with the finger movement.

SUMMARY CONCLUSIONS

1. The ability to execute movements in a simple time rhythm does not stand in any appreciable correlation with good penmanship. The natural rhythmic performance of individuals is rather a correlate of maturity, manifesting itself quite early in some cases, and attaining a comparatively high degree of regularity by the time of adolescence.
2. The ability to follow an imposed rhythm closely is characteristic of the good writers. Poor writers are deficient in this respect.
3. The poorer writers and younger children tend to lag behind an imposed beat, while the better writers and older children have the ability to anticipate the beat.
4. The imposition of rhythm tends to increase the proportionate amount of time spent at rest thus slowing down the movement as the stroke remains fairly constant in duration.
5. The imposition of rhythm does not immediately aid in the securing of a more exact time rhythm except with those who have no fixed habits of natural rhythm or who are using

motor agents which have not yet been brought under control.

6. Children spend a greater proportionate time at rest than do the adults, the stroke being accomplished nearly as quickly as in the case of adults.
7. In general, the total stroke is recognized as the unit of movement, and as such receives the rhythmic emphasis to a far greater extent than is the case with either the rest or period of movement.
8. The use of arm movement seems to be more favorable to rhythmic movement in the case of adults than does finger movement, although this tendency is negatived when an imposed rhythm is followed.
9. Less time is given to rest proportionately when are movement is used than when finger movement is used, showing that the arm either has a more immediate initiatory control or that it is less rapid in movement, at least in this type of stroke.
10. The better writers show in general less differentiation between the records of finger and arm movement than do the poorer writers.
11. The better writers exhibit a better control of both finger and arm movement in the adaptation to imposed rhythm.
12. The finger movement is brought under control at a later period than the arm in the child's development.

PART THREE

A New Method for the Micrometric Investigation of the Handwriting Process and Product and a Study of Typical Results with the Use of this Method with a View to Noting and Defining Some of the Elements of Time and Organization Involved.

Previous Methods of Measuring the Changes of Inner Speed.

The need of arriving at a detailed and accurate measure of the inner speed of handwriting has already been noted (p.4). Several different methods have been used with varying degrees of success. They will be briefly summarized here so that the reader may have an inclusive view of the steps in the development of method leading to the one herein designed and described.

In 1893 Binet and Courtier described (1) experiments in handwriting in which the Edison stylus pen was used. This instrument, originally designed for us with mimeograph stencils, was quite heavy, containing at one end a small motor which operated a cam so as to cause a plunger point at the writing end to alternately project and be withdrawn, piercing the writing surface about each 17th of a second. It was noted that as the instrument was drawn across the page in a stroke movement the perforations made were farther apart at the middle of the stroke and bunching at the ends, indicating greater speed of movement at the mid-portion of the stroke. The weight of the stylus, the friction incident to the point perforating the surface, the coarseness of the measure, the vibration of the instrument, etc., prevented any accurate, detailed study of actual writing movements, yet the findings revealed the value and need of further analysis.

Jack reported (4) in 1895 the use of a distinctly different method of analysis, one which yielded more accurate results for certain types of strokes. A coatedglass plate was fixed at the end of a vibrating fork in such a way that the

writer could readily write upon it. While the fork was in motion the subject would make a stroke upon the surface with a pointed instrument; the tracing of the stroke being clearly shown by the removal of the coated surface. If the direction of the stroke were transverse to the vibration, the tracing would appear as a waving line. It was found that successive waves were gradually more compressed toward the beginning and end of the strokes, and farther apart in the middle, showing conclusively that the speed increased at the middle of the stroke and slowed down at its terminus and initiation. But although the conditions were quite normal as to friction and the use of a writing instrument, and the measurements in general quite accurate, the method was not applicable to the study of curved strokes such as occur in writing, or to the analysis of the more minute strokes incident to penmanship.

McAllister (5) reported several studies in 1900 in which he made use of a method having some points in common with that used by Binet and Courtier. The subject wrote on a soot-coated metal plate with a sharp pointed stylus. This stylus was in circuit with an electric current through the metal plate, this current being broken and established about every 15th of a second. At the instant when the current was established a small spark was made at the point of contact of the stylus with the metal plate. This spark registered itself by the removal of a speck of soot from the coating of the writing surface. Similar results were secured as by previous methods. However, except for lack of friction and greater lightness of the writing implement, the method had no great advantage over some methods previously used, either as to

naturalness of conditions, or accuracy of results for detailed study.

A great advance in the technique of methods was attempted by Freeman (2), who presented the results of an investigation in which he made use of a specially designed apparatus enabling him to make a detailed study with great accuracy. The subject wrote while seated at a table in the ordinary manner. Underneath the sheet on which the writing was done was a wide inked ribbon, and just below that a wide strip of paper moving from right to left. The tracing of the writing was received upon this strip, not in legible form, but in a laterally extended line, so that a straight line drawn perpendicular to the line of writing would be traced as a complex curved line running from the left downward and toward the right, showing evidence of slow speed at the beginning and end of the stroke, and of comparatively rapid speed at the middle. The more rapid the speed the more the inclination of the tracing would tend toward the vertical.

Exact time computation was gotten through the medium of a time marker which recorded its measure of one tenth of a second continuously on the margin of the moving strip. Analysis of the records was made quite arduously, but with a high degree of accuracy, by a careful measuring off of successive equal lengths of the line of writing (the exact path of the penpoint), noting the vertical placement of their limits in the tracing and the units of time taken to each as indicated by the horizontal distance on the time scale be-

tween these points. By this method exact analysis of the inner speed could be made to quite a degree of detail, but the method was not adapted to the study of smaller forms as used in penmanship, and the building up of a speed curve must of necessity be very painstaking. However, the method offered the first satisfactory means of a study of inner speed relations.

Photography was introduced into the study of penmanship by Freeman (3) who made use of motion pictures. This method was chiefly valuable in the study of the movements of the arm, hand and finger as used in the handwriting process, but made available also an analysis of inner speed relations in the following way. The individual negatives were imaged one at a time in enlarged form by being projected on a screen. Such an image was projected and the position of the penpoint noted, as well as the position of the arm and fingers. The next one of the series would then be projected, and the position of the penpoint would again be noted on the same screen surface. The process would be continued in this manner throughout the written passage. The distances between successive positions of the penpoint were then measured and speed curves constructed. The time intervals between successive images was about one twenty-fifth of a second. The method did not yield absolutely accurate results because of the inability to definitely indicate the exact position of the penpoint in the projected image due to the diffusion of light.

The writer acknowledges his indebtedness to the designers of all of these methods, nearly all of which have contributed items of method, both desirable and feasible, in the construction of the apparatus used by him and described in the following pages.

1. Binet, A. and Courtier, Sur la Vitesse des Movements Graphiques: Revue Philosophique, 1893, 35; 664-71.
2. Freeman, F.N. An Experimental Study of Handwriting: Psych. Monog. 1914, #75.
3. Freeman, F.N. The Handwriting Movement, Educ. Mon. 11, #3, Aug. 1918.
4. Jack, W.R. The Analysis of Voluntary Muscular Movements by Certain New Instruments. Journal of Anat. and Physiol., 1895, 29: 473-9.
5. McAllister, C.N. Researches on Movements Used in Writing. Studies from Yale Psych. Lab., 1900; 8: 21-63.

Description of Apparatus.

In nearly all methods, thus far successfully used in measuring the rate of motion of the penpoint in handwriting movements, there has been an attempt to locate certain points in the actual traced line of writing which are variable as to their distance from each other, but related by a constant scale of time, so that the bunching of points would indicate a decrease of speed, and their separation an increase.(1) The method used in this investigation has been devised in line with the same principle. The special apparatus employed may be considered in two groupings: (1) that which was necessary for the making of a record, and (2) for the measuring of a record.

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(1) An exception occurs in the case of the first method used by Freeman, as noted in the preceding section (p. 73) in which the units of distance over which the pen passed were regarded as constants and the time units as variables.

The Recording Apparatus

Simply stated the method for which the apparatus was specially adapted consisted of photographing the point of the pen at regularly timed instants with a view to noting the relative distance through which it passed during the intermediate intervals.

In order to photograph the point of the pen alone it was found necessary to isolate it. This was effected by an intensification of the point of the pen so that it would photograph easily; at the same time all other objects in the photographic field were subdued so that the image of the penpoint alone would be recorded on the negative. The intensification of the point of the pen was obtained by illuminating a ball reflector attached to it. The room was darkened and the photographic field flooded with a reddish light so as to neutralize the actinic properties of all light rays save those reflecting from the ball. The source of illumination of the reflector was an electric arc light. An electric-motivated tuning fork which cut the rays of light passing between the arc and the reflector provided the constant scale of time, corresponding to its vibrations, so that during each unit of time, the ball would be illuminated for approximately one-half of the unit, then shut off from the light for an equal period. A specially devised camera was placed in a position vertically above the photographic field, so that, as the pen was held in writing position within the

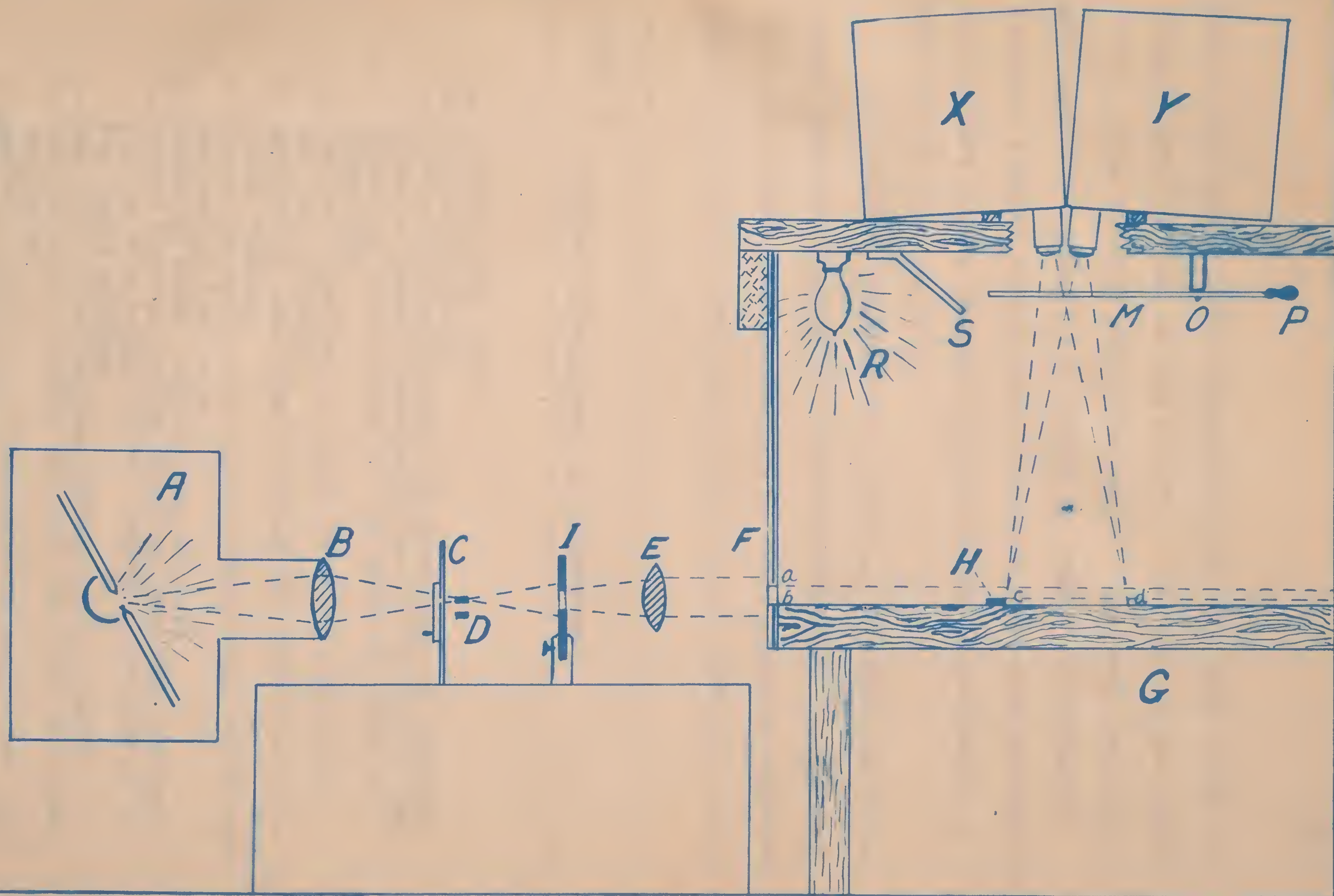

FIG. 3 – CROSS SECTION LATERAL VIEW – SHOWING GENERAL ARRANGEMENT OF PHOTOGRAPHIC APPARATUS

field, the ray of light reflecting from the ball would be imaged upon the film in the camera. As the pen was moved about in the writing plane the path of movement was photographically recorded as a series of dashes of different lengths, varying as the rate of motion, but each corresponding in time to the absolute period of the illumination of the ball in each position.

The detailed plan of the apparatus is essential to a proper understanding of the method employed. In Figure 3 is shown a cross-section diagram of the apparatus which reveals the relative position of the various essential parts.

Figure 3. General Arrangement of Apparatus

A. Electric arc light
B. Condensing lens
C. Screen with adjustment for apertures of various sizes to permit the definition of the light rays.
D. Vibrating fork placed at the point of fucus of light rays.
L. Screen interposed to limit the rays vertically and horizontally.
E. Condensing lens used to bring the rays into parallel relation
F. Screen to define the light rays passing above the surface of the table
G. Table on which handwriting is done
H. Holder used to fasten sheet of paper to the surface of the table and to prevent illumination of the paper surface
R. Red light flooding the surface of the table
S. Screen placed between the red light and the camera lenses
M. Movable screen placed between the camera and the writing surface
X & Y. Cameras used in photographing

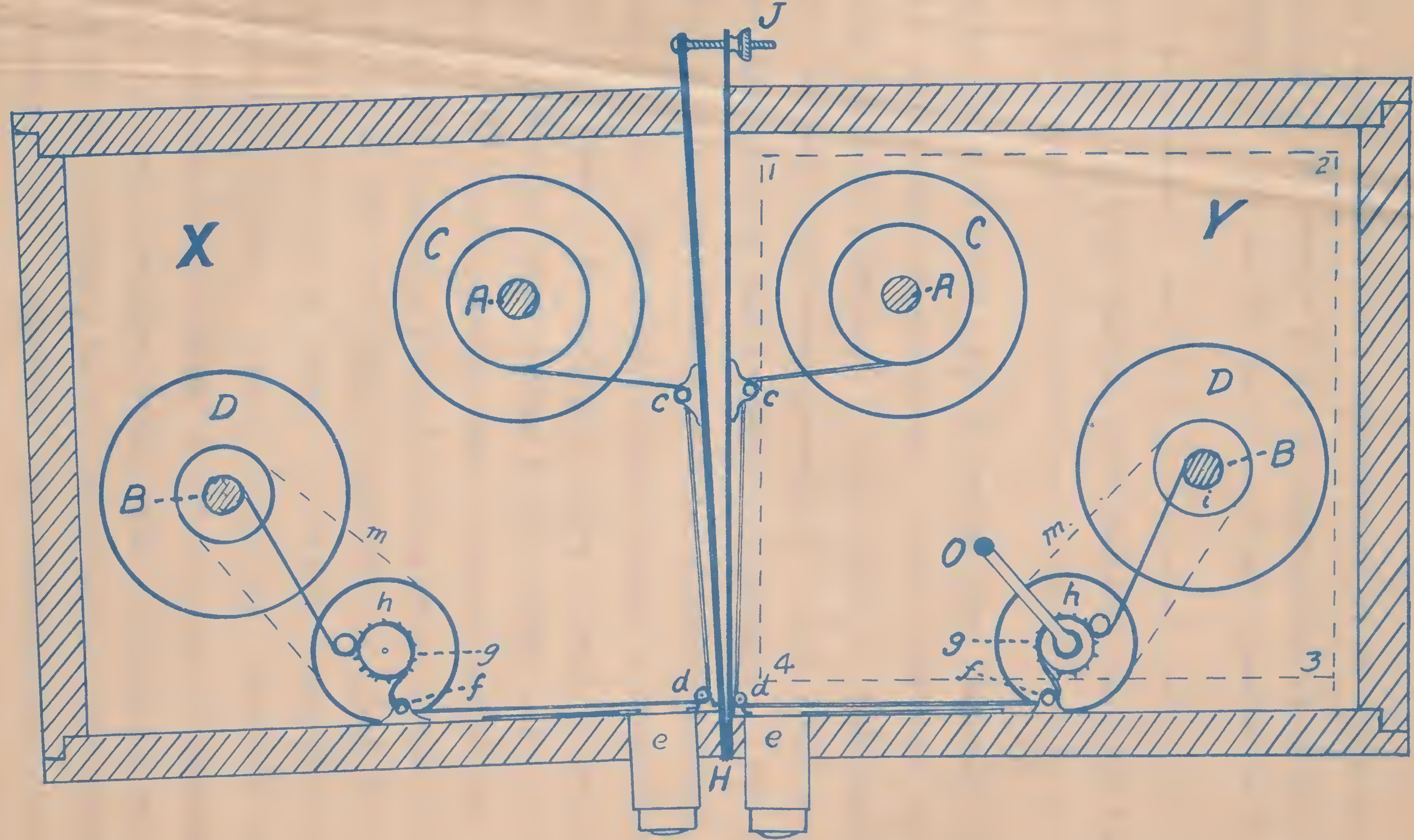

FIG. 4 — CROSS SECTION VIEW OF CAMERAS — SHOWING CONSTRUCTION AND METHOD OF THREADING FILM.

The tuning fork (D) was standardized at 50 vibrations per second. The camera (X-Y) is represented in detail in Figure 4. It was in reality a double camera, being made

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Figure 4. Special Camera Cross Section - Lateral View

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up of two cameras (X) and (Y) which were identical in shape, size and general construction. Their functions were, however, slightly different. The camera (Y) was designed to take ordinary stationary photographs which would reproduce the exact path of the penpoint in miniature. But it is evident that, where lines made in writing coincided, the dashes in the photographic record would be inextricably intermixed (see p. 88); also a period of rest of the pen at any point would be evidenced in the record only by a dot of greater or less intensity with no indication of time spent. To obviate these difficulties the special camera (X) was devised in which the photographic film was kept in steady motion at the rate of about 1 inch per second during the period of exposure. Moving across the focal area parallel with the general direction of the writing and opposite to it, the record produced represented a stretching out of the path of the penpoint, in the same manner as the tracing used by Freeman (p.73), and not only differentiated all strokes clearly, but indicated the amount of time spent at rests.

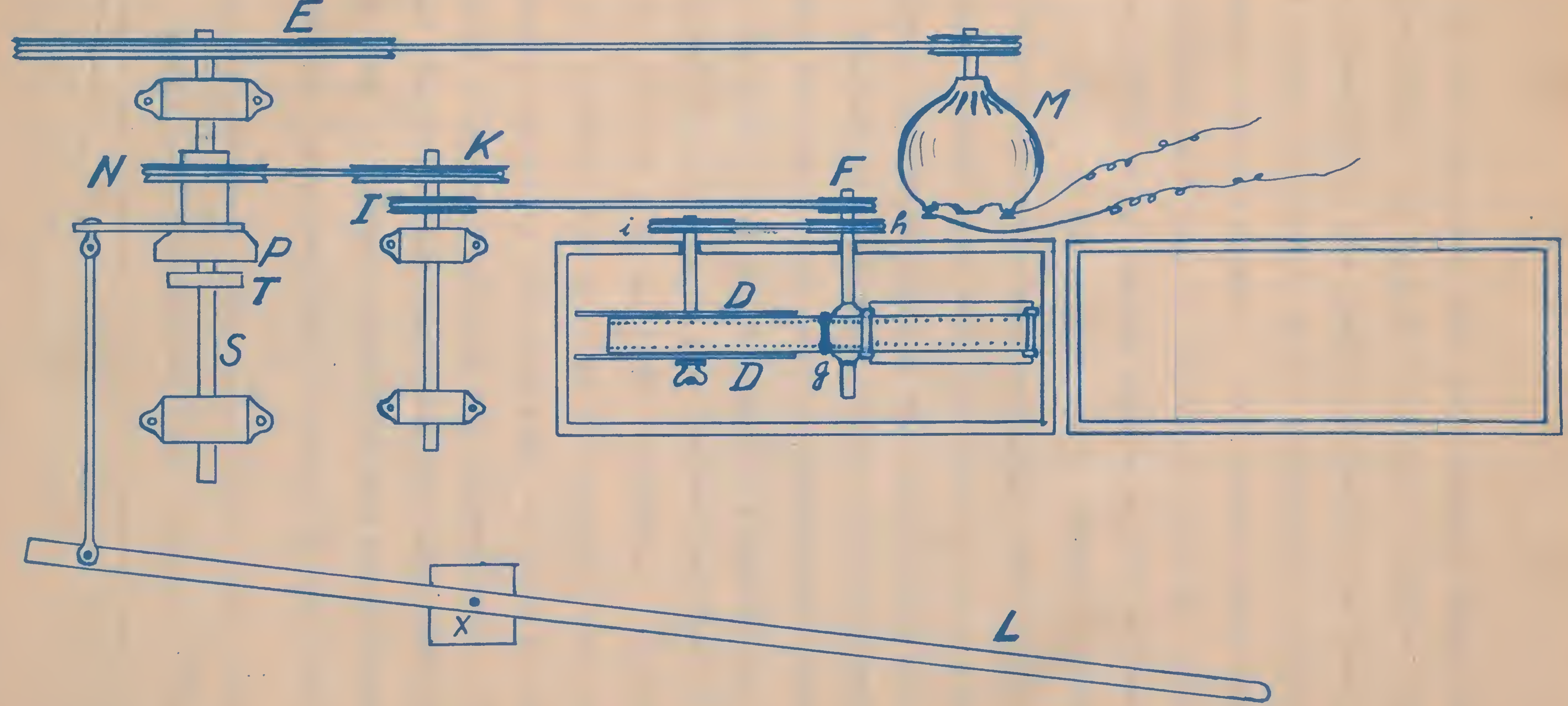

FIG. 5 – BIRD'S-EYE DIAGRAM OF CAMERAS – SHOWING MOTOR AND GEAR CONNECTIONS FOR MOVING FILM

Since it was necessary that both cameras should bear upon the same field, the lenses (ee) were placed as near together as possible at the inner extremeties of the camera floors. A screw adjustment at (J) permitted a variation in the direction of the lenses. The cameras were solidly fixed in position (see Fig. 3) directly above the field (c-d) approximately seven inches square on the surface of the table (G) and at a focal distance of about 26 inches.

Both cameras were similarly threaded with standard motion picture film in very much the same way as any motion picture camera, automatic winding and tension devices being provided. The essential difference in the two cameras was the provision for the motive power in turning the sprockets and moving the film. In the camera (Y) a handle (c., Fig. 4) was attached to the axis of the sprocket so that it could be turned at will for long or short distances. In the case of camera (X) however, the axis of the sprocket was connected with an electric motor by bolt and gear as shown in Figure 5, which gives a birdseye view of the connections. The lever (L) was placed so that the operator could start the movement of the film by forcing contact of the cam (P) with the friction gear (T), the shafting (S) being in constant motion.

Figure 5. Camera and Gear Connections. - Superior View

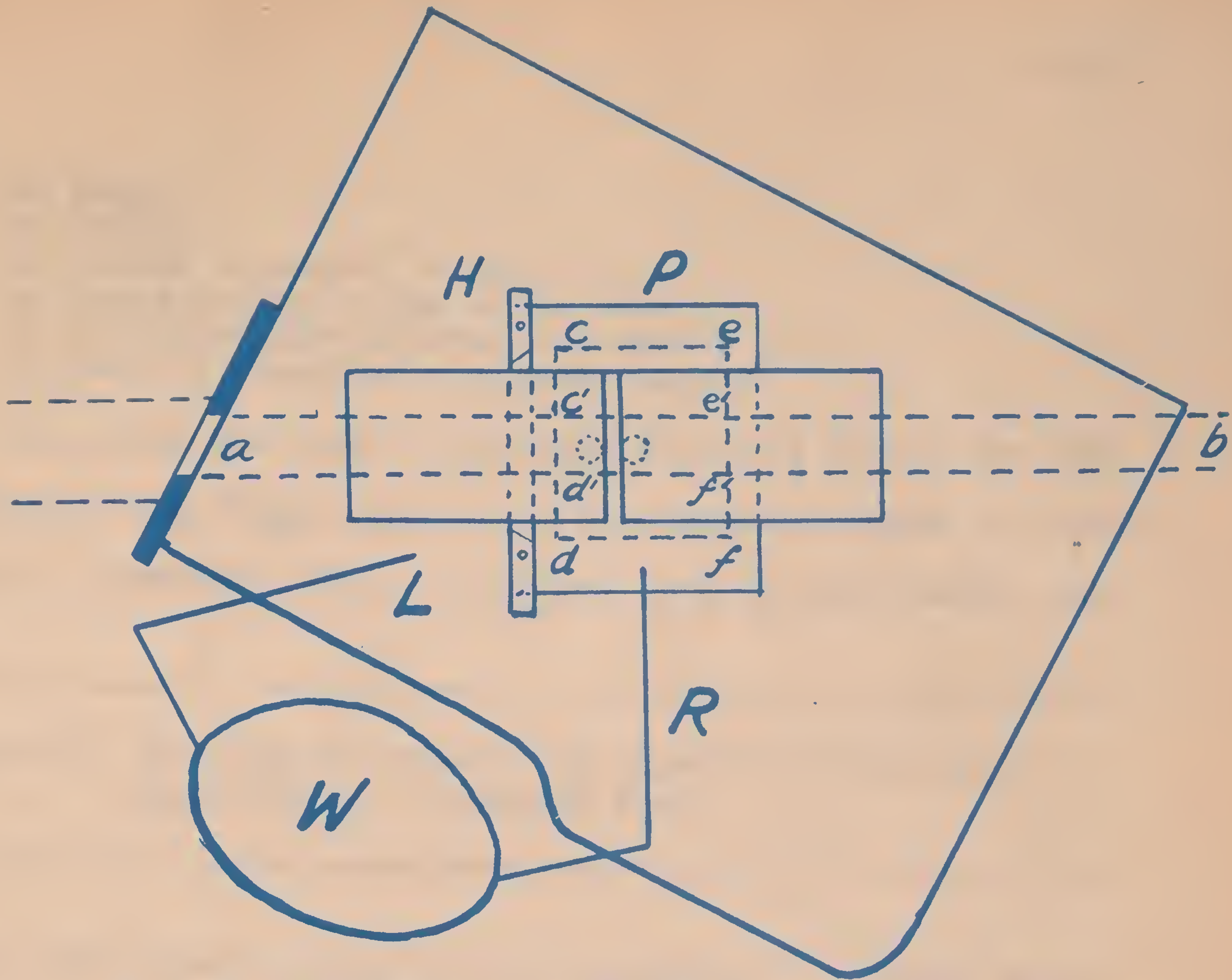

FIG. 6. PLACEMENT OF TABLE, WRITER AND WRITING SURFACE WITH REFERENCE TO THE LIGHT RAYS AND THE CAMERAS

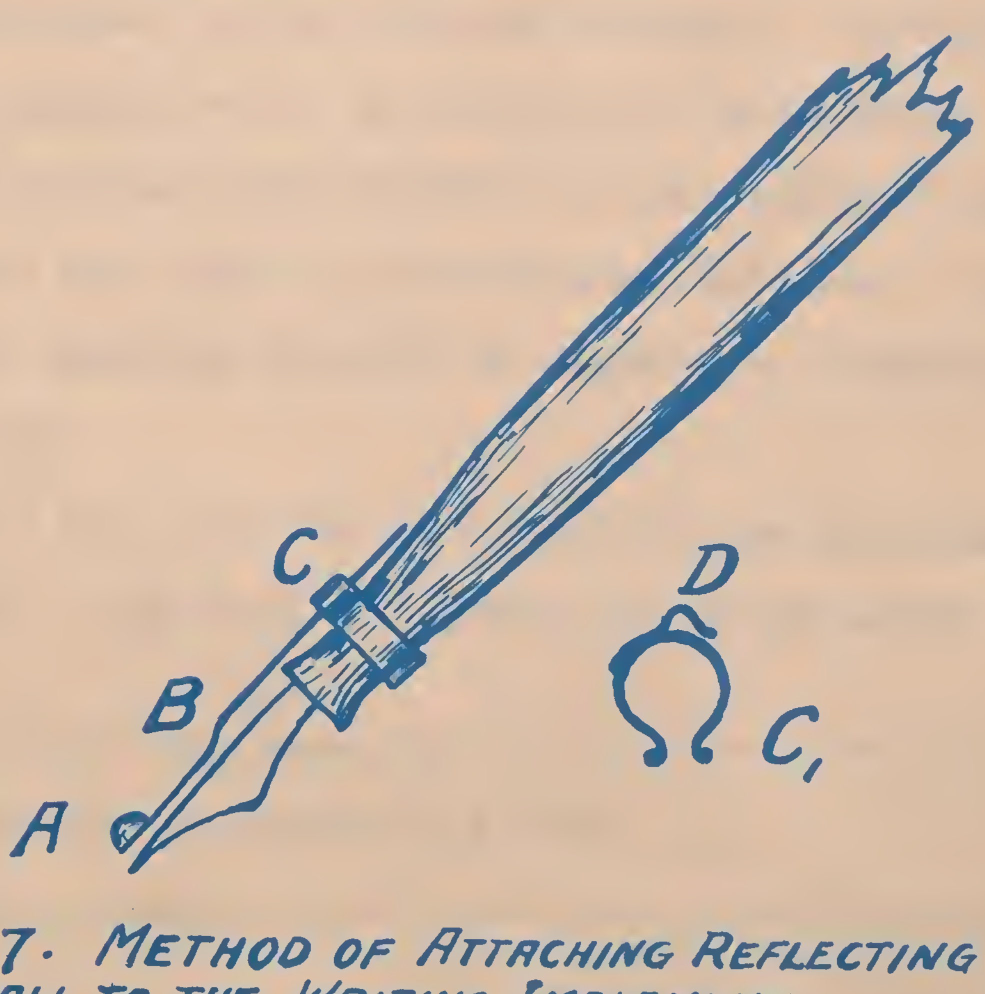

FIG 7. METHOD OF ATTACHING REFLECTING BALL TO THE WRITING IMPLEMENT.

M. Motor
R. Pulley
N. Pulley attached to cam P
P. Cam turning on the shaft (S)
T. Friction gear attached to shaft (S)
L. Lever to control the gear contact

The table was set at an angle of about 60° to the direction of the light rays (a-b) as shown in Figure 6, which gives an overhead view. This was done to accommodate the

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Figure 6. Position of Writer and Paper in Relation to Light Rays. - Superior View

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writer, who, when sitting in the position (W), would be in the best recognized relation to the writing surface (P), with left forearm resting (L) on the table and right forearm (R) perpendicular to the line of writing. The paper was fixed in position so as to cover the photographic field (cefd) and the writing done within the more limited area (c'e'f'd') where the light rays were most intense. The writing surface could be shifted as desired by lighting the holding strip (H).

In Figure 7 is shown the placement of the reflecting ball on the pen. The ball (A) which was of nickeled steel

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Figure 7. Reflector Attachment to Pen

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was flattened on the under side so as to prevent downward

radiation of reflecting rays and bring the center of the rotation of the ball as near as possible to the axis of the pen, and was fixed to the extremity of a small wire (B). A spring band (C), another view of which is shown in the small figure (C_1), which could be attached firmly to any ordinary writing instrument, had soldered to it the small spring (D) under which the wire (B) could be placed securely in any desired position. When a record was made it was essential that the ball reflector should be adjusted so that it would be just over the penpoint as viewed from above. These adjustable features enabled the subject to use his own pen or pencil, or select one which would give most suitable service. A fountain pen was generally used because of the greater convenience in inking the pen point. To prevent diffusion of light, all metal parts, including the penpoint, except the nickeled ball, were enameled with a dull black coat.

So that the subject would have sufficient illumination to prevent his writing under unnatural conditions in a darkened room, an orange colored lamp (R, Fig. 3) was placed so that its rays would be directed over the surface of the table. It was found that a light strong enough to make the lines and writing on the paper clearly visible to the subject could be used without danger of impressing the film.

An index device was provided, consisting of a wedge-shaped block with blackened surface, and small pieces of white cardboard on each of which was printed a letter or figure. The block was placed flat on the table within the

photographic field, with the thin edge toward the source of light, the letters or figures desired were placed upon it and exposed to the films for a second. The films were now turned ahead about an inch, and the record made. The written record was similarly indexed for convenient reference.

Two small tacks, with reflecting ball bearings attached to the heads were stuck into the writing paper just above the line of writing and about three inches apart, care being taken not to put them in direct line with each other. These were recorded on the stationary film as two dots, and on the moving film as two straight lines of dashes, and served as guides in the later analysis of the records, especially in superimposing the image of the moving film upon the tracing of the stationary film. (p.89).

Electric switches were conveniently placed so that the experimenter, standing back of, and to the right, of the subject, could control the lighting of the red light (R, Fig. 3), the starting and stopping of the electric motor (M, Fig. 5), and the general illumination of the room. The lever (L, Fig. 5), which controlled the connection of the gear for the moving film and handle connected with the screen (M, Fig. 3), were within easy reach.

In summary the steps in recording were as follows: (1) Threading of the cameras. (2) Turning on the arc light. (3) Darkening of the room. (4) Starting the tuning fork. (5) Testing of the light rays for brightness and place and adjustment of the vibrating fork. (6) Indexing of the re-

cord to be photographed. (7) Turning on of the red light. (8) Subject practises. (9) New writing surface placed in position and ball bearing guides fixed in position upon it. (10) Subject told exactly what he was to write and given order to start. (11) When the subject reached that part of the exercise decided upon for record the handle (Y, Fig. 3) and the lever (L, Fig. 5) were simultaneously operated so as to expose the photographic field and start the moving film. (12) When the essential part of the exercise had been covered the handle and lever were brought back into normal position, the subject told to stop and the lenses were recapped. (13) In case more than one exercise was desired from the one subject, the films were wound along and a new index made, and the process repeated.

Much preliminary operation was necessary before the many variable factors in the apparatus and method could be standardized so as to give satisfactory results. This was finally accomplished by isolating them and dealing with them singly or in combination until proper conditions were obtained. Among these variables may be mentioned such things as the source of illumination, size of apertures, the vibrating fork, the lenses, etc.

The developing of the film required a great deal of care but none which a fairly well trained photographer could not meet satisfactorily. No positive film was made, not merely as a measure of economy, but because the negative film as projected gave a clear, definite image with little diffusion of light and with good general illumination of the screen.

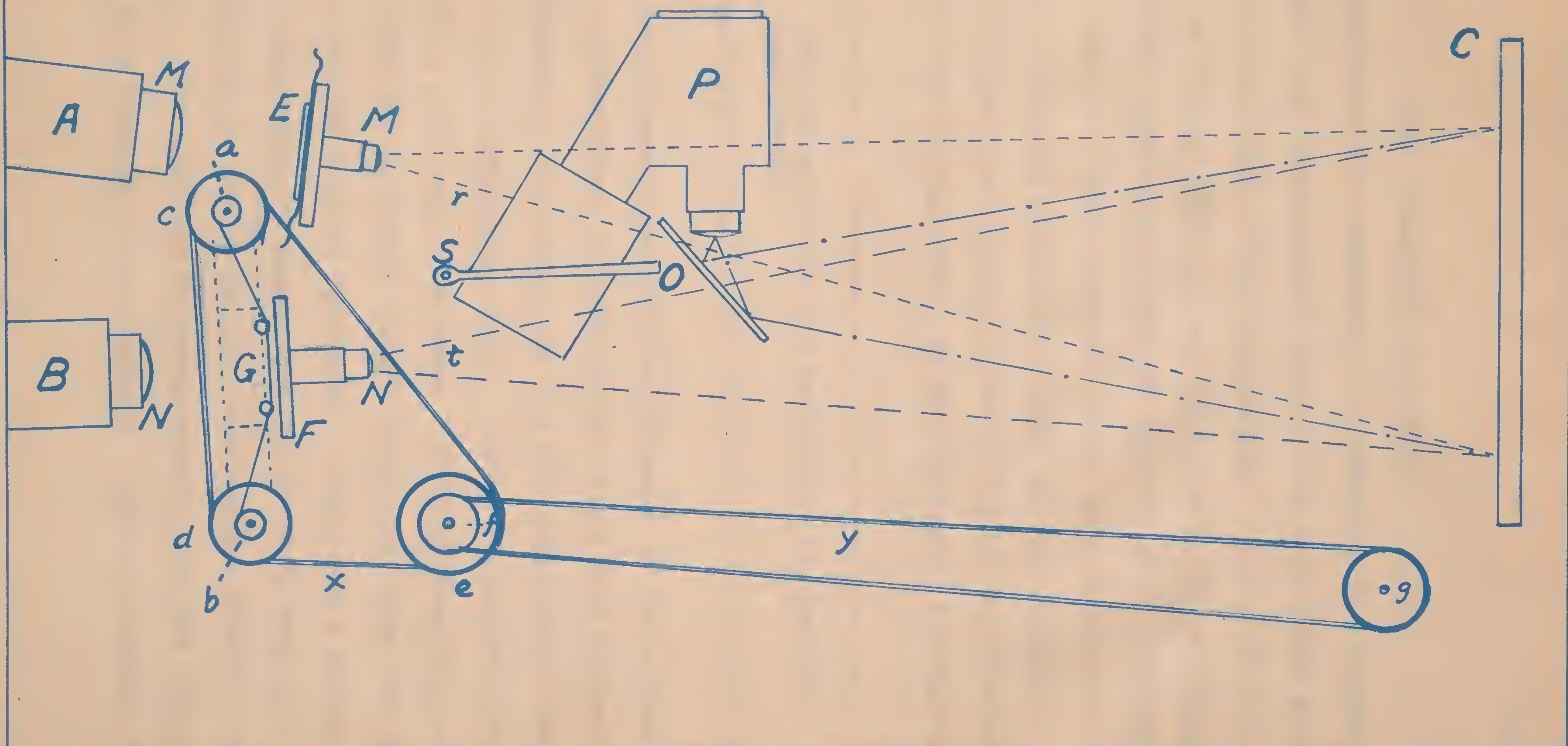

FIGURE 8 PLAN OF APPARATUS FOR PROJECTING IMAGES FOR MEASUREMENT — SHORTENED

The Measuring Apparatus

The mechanism for measuring the records was designed to so magnify the photographed images that they could be successfully analyzed and studied in detail. Any part of the stationary or moving film record, or the original writing, could be imaged upon a large screen by the use of projectoscopes and could be manipulated at will, so the observer could make a thorough comparative study of the records.

The superior view diagram given in Figure 8 shows the placement of the various parts of the apparatus in relation

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Figure 8. Plan of apparatus for projecting images for measurement

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to each other, though the relative distance of the screen from the projectoscopes is much greater than here indicated. Two projectoscopes were used; one (A) for stationary, and the other (B) for the moving film. Nitrogen electric bulbs of from 500 to 1000 c.p. were used. Both projectoscopes were placed so that the projected images would fall upon the large screen (C), set at a fixed distance. There was a slight horizontal distortion of images due to the fact that all lights could not be placed in the same angular relation to the screen. But this was of small amount, and was easily cared for by a turning of the screen. Special holders (E

and F) were designed to keep the respective films in position for projection. The stationary film was held by a spring between two glass plates (E). The holder (F) for the moving film was in the form of a carriage (G) through which the film could be moved as it was unwound from spool (a) and wound up on spool (b). A groove in the holder permitted no lateral movement of the film. The spools holding the film (a) and (b) were provided with fixed pulleys around which the belt (x) passed. This belt also engaged the pulley (e) fixed upon the pulley (f). The long belt (y) extended from this pulley to pulley (g) which was placed to the right of the screen (C), so that the film could be moved forward or backward by the operator while seated near the screen. The carriage (G) was adjustable to any position desired.

A screen (O) placed between and to the front of the projectoscopes was swung on a pivot so that it could be used to shut off the rays from either projectoscope or allow both to project images coincidentally on the same field. (Note the dotted arc indicating the path of this screen and its three possible positions (r, s, t).

A reflectoscope (P) was placed in front of and below the level of the projectoscopes in such a position that the image of the original writing as projected on the screen (C) coincided with that of the corresponding stationary photograph as projected by the lantern (A).

The screen (C) was so constructed and attached to its vertical frame that it could be raised and lowered, moved sideways in either direction, or set at any slant, thus permitting the superposition of the tracing of any image upon the projection of the image as desired. (See below).

The Technique of Analyzing Records.

The process of measuring and studying the records involved the human element to a greater extent than the making of the records which depended for success largely on the ordered operation of mechanical agencies. Consequently the reliability of all measurements and conclusions was conditioned by the expertness and constant carefulness of the observer.

A large sheet of drawing paper was fixed upon the screen and a tracing made of the enlarged image of the original writing as it was projected by the reflectoscope in a darkened room. The stationary photographic record was then projected and made to approximately coincide with the tracing. The board screen was then moved about until the coincidence was complete. If there had been any serious turning of the ball reflector at the point of the pen, or any falsity in the assumption that the reflector, so placed, would definitely trace the line of writing, it would have been evidenced by noticeable deflections in the coincidence of the lines of the two images. Such was not the case, however, in any of the records studied.

The dashes, which could be clearly distinguished and differentiated in the image, as projected from the stationary

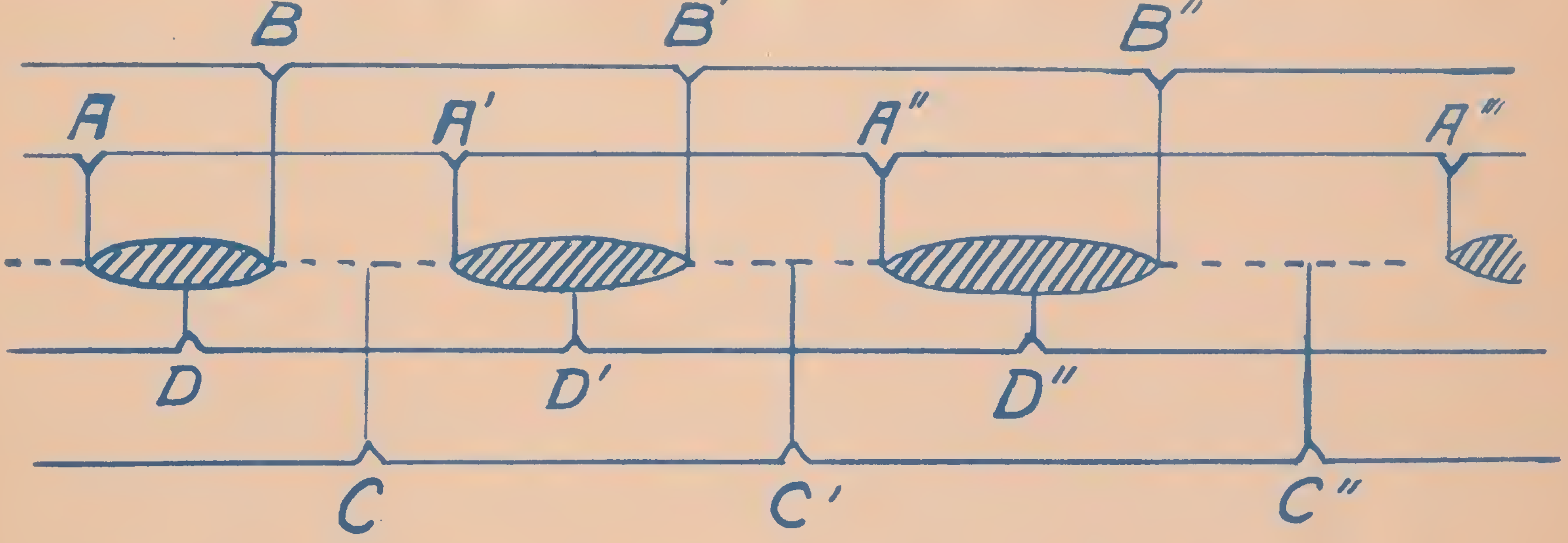

FIG. 9 - DIFFERENT POSSIBLE LIMITS OF TIME INTERVALS OF .02 SECONDS EACH IN THE PROJECTED IMAGE.

film, were now indicated by marks drawn perpendicularly to the line previously traced. The question as to where these marks should be placed, so as to most effectively indicate the time periods of one-fiftieth of a second, required some preliminary investigation. Four locations naturally suggest themselves as indicated in Figure 9; the beginnings of

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Figure 9. Different possible limits of measures for space intervals of one-fiftieth of a second each

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the dashes, giving the measures (A-A', A'-A", etc.); the ends of the dashes, with the measures (B-B', B'-B", etc.); the middle of the spaces between the dashes, measured by (C-C', C'-C", etc.); and the middle of the dashes (D-D', D'-D", etc.). The latter were selected as limits, as experiment showed that these points could be fixed upon quite definitely as compared with the others, principally because the dash came into prominence and disappeared very gradually, especially where the movement was rapid, so as to leave no definite edge, while it did exhibit rather clearly the point at which there was the greatest degree of illumination. The measurement of some records was attempted by a combination of all the above mentioned methods, but the results gave no more accurate record so as to justify the extra labor involved.

The observer marked the midpoints of the dashes throughout that part of the exhibit desired for study, placing a

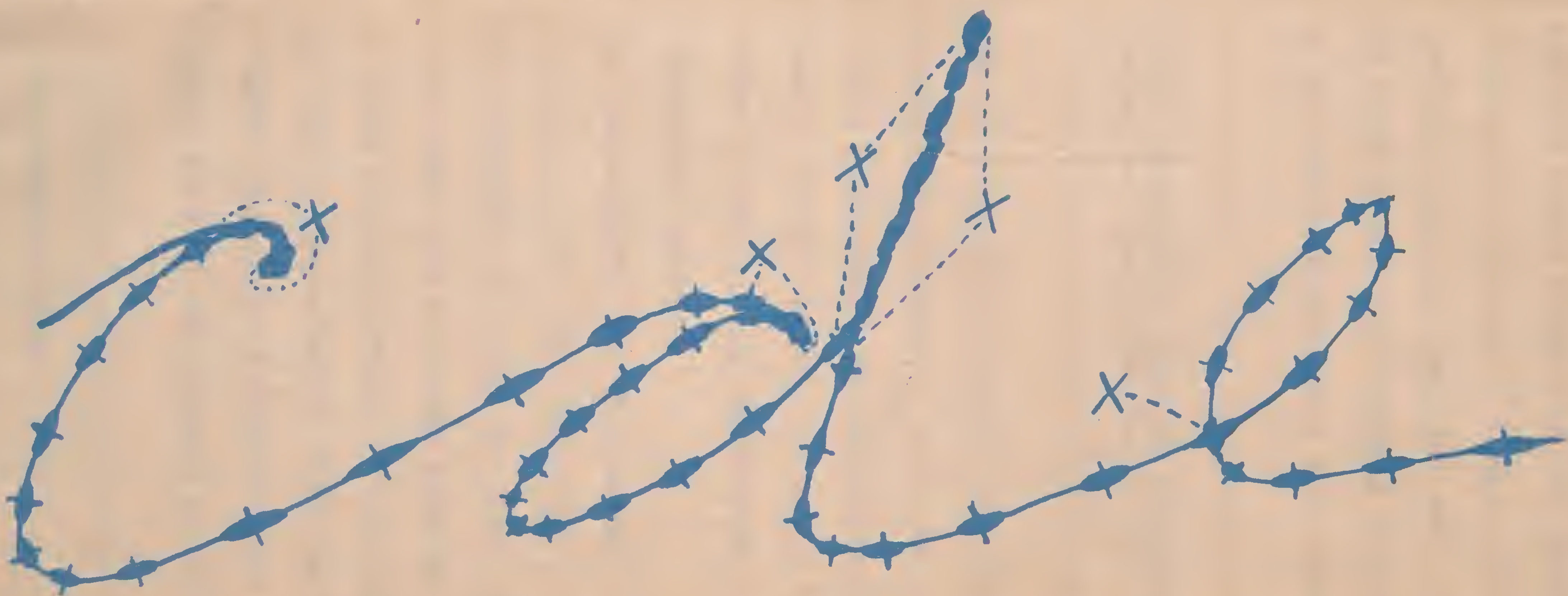

FIG. 10 - REPRESENTATION OF THE PROJECTED IMAGE OF A STATIONARY FILM RECORD AS SUPERIMPOSED ON THE TRACING OF THE IMAGE OF THE WRITING.

bracket (x) opposite any portion where there was any confusion and intermingling of lines, and also near those points where it was considered possible that the penpoint had come to a full stop. Figure 10 shows a greatly reduced copy of an exhibit at this stage of the marking process, and includes

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Figure 10. Projected image of stationary film as superimposed on original tracing and intervals indicated

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the traced line of the original writing as written by Subject No. 1, the approximate outlines of the dashes, with the indication of their midpoints where definitely discoverable, and some examples of incompleteness in the record, as shown by the mark (x), due to confusion of lines, and uncertainty as to the exact position and number of dashes.

After a record had been transferred in this manner the corresponding film containing the record made with the film in motion, was placed in its carriage (G, Fig. 6), the rotating screen was turned so as to shut off the rays from the stationary film, the moving film was then wound on its spools until that part of the image which corresponded with the beginning of the stationary record being studied came into view. In Figure 11 is shown a diagram view of the screen as it ap-

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Figure 11. Method of using the moving film.

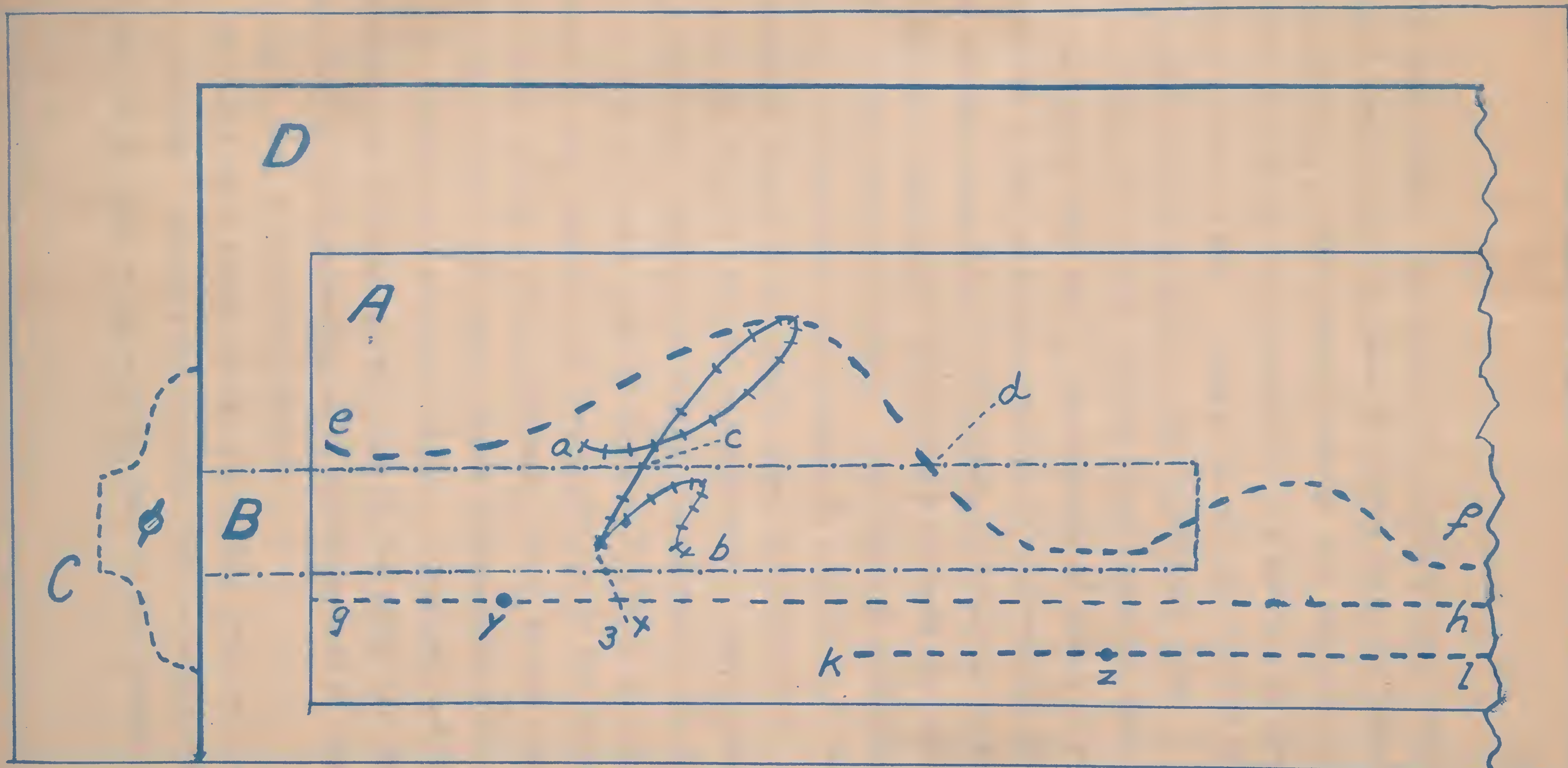


FIG 11 - APPEARANCE OF PROJECTED IMAGE OF THE RECORD OF THE MOVING FILM AND THE METHOD OF IDENTIFYING TIME INTERVALS.

pears at this stage. The letter "h" is here being analyzed. The letter form is clearly shown as traced from the reflectoscopic projection on the drawing surface (A), and with the cross-bars indicating the midpoints of the dashes, as projected from the stationary film. Points (y) and (z) are the loci of the guides as photographed on the stationary film.

The moving film record appears imaged upon the screen in the dotted waving line (e-f), the identity of which is easily recognizable by the vertical placement of its various elements. The up and down movements of this line are found to correspond as to absolute height with the successive upward and downward strokes of the letter as imaged. The carriage containing the film, and the screen are adjusted at such an angle that the projected images of the guide lines (g-h) and (k-l) coincide with the loci (y) and (z) respectively. The operator, seated before the screen, now turned the pulley at his right so as to move the film back and forth as desired, in order to identify each dash and test the exactness of the location of the marks already placed, care being taken in all movements of the film, to see that there was no marked deflection of the guide lines from the locus points. Whenever, under these conditions, the midpoint of any dash in the image did not coincide with the corresponding mark, the placement of the mark was tested, and, if need be, revised.

The marks were placed in the incomplete parts of the record as follows: a long t-square (B), with an adjustable head (C), was set at such an angle that, when it was placed against

the edge of the screen the blade extended parallel to the guide lines. The square was then brought into position so that the edge rested at the midpoint of a dash in that portion of the image that was in question, and a mark was made where this edge of the square crossed the traced line of writing. This process was repeated until the blank spaces in the record were properly filled out. The correspondence of the midpoint of dash (d) with the mark (c) is notable in Figure 11. At points of suspected rest, as at the bottom of the second stroke on the "h", the dashes were carefully identified, and the number which extended in a straight line in the image were counted, and this number (in this case 3) noted in a position near the (x).

The operation of marking the exact location of dashes was continued throughout the entire line of movement of the pen point without regard to the lifting of the pen from the page at the end of words, etc. Whenever the pen was lifted so far as to prevent photographic record of the movement, due to taking the reflector ball out of the bath of the light rays, the amount of time spent could be computed by counting the number of dashes in the guide lines which crossed the locus points as the film was wound slowly along to a point where the dashes reappeared.

After the exhibit had been completely marked according to the plan thus outlined, the record as placed on the drawing paper was ready for further analysis. The spaces between the marks, designating the midpoints of the dashes, were first

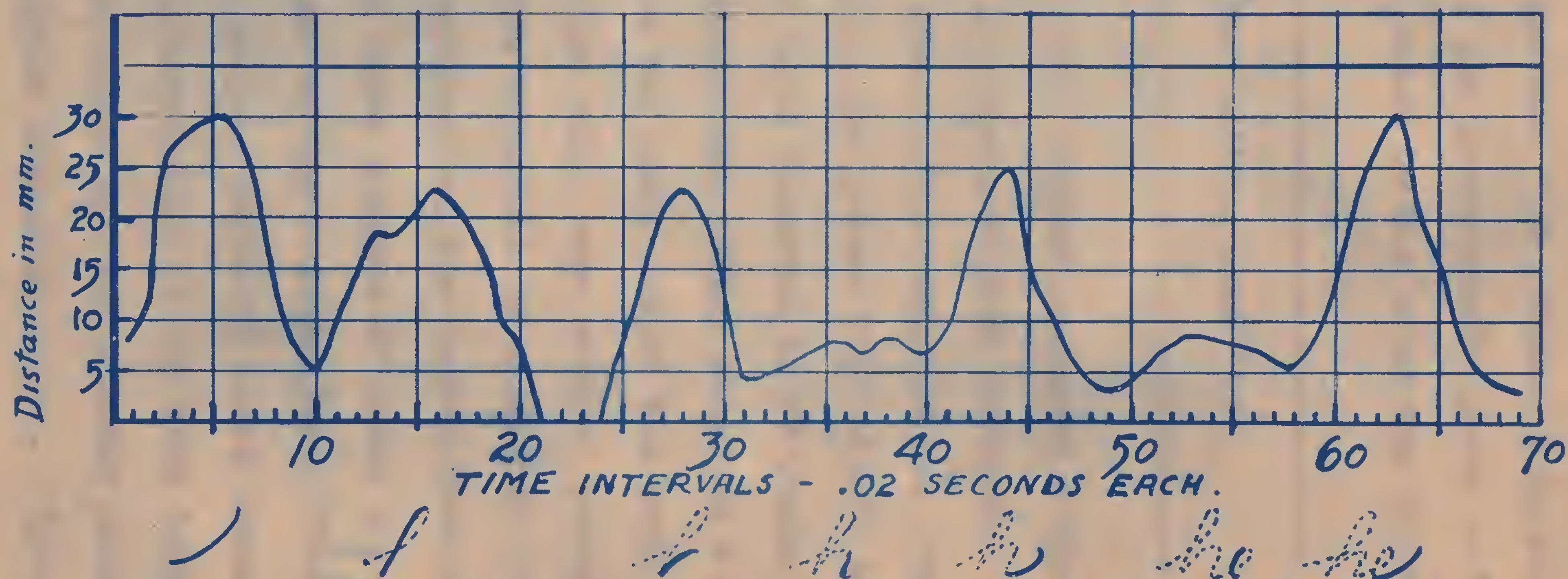
carefully numbered in order from the beginning to the end of the exhibit. At points of rest allowance was made for the number of time spaces, which were evidenced, not in terms of distance, but in the number of dashes noted from the moving film.

The operator now measured these spaces in order in terms of millimeters. Although various methods suggested themselves and were tried, such as the use of the compass, the observer finally decided on the use of a pliable strip of millimetric rule, which could be laid along the line of any curve and the measure could be read from it easily and correctly at a glance. These measures were tabulated as shown in Table 11, where a typical arrangement is given. The exercise "he" here studied is divided into its seven natural strokes. In the second column are noted the time intervals, each one-fiftieth of a second long, in order; in the third column the speed is recorded, or the number of millimeters of the enlarged image which were covered in each fiftieth of a second. The total length of each stroke is also noted for comparative purposes.

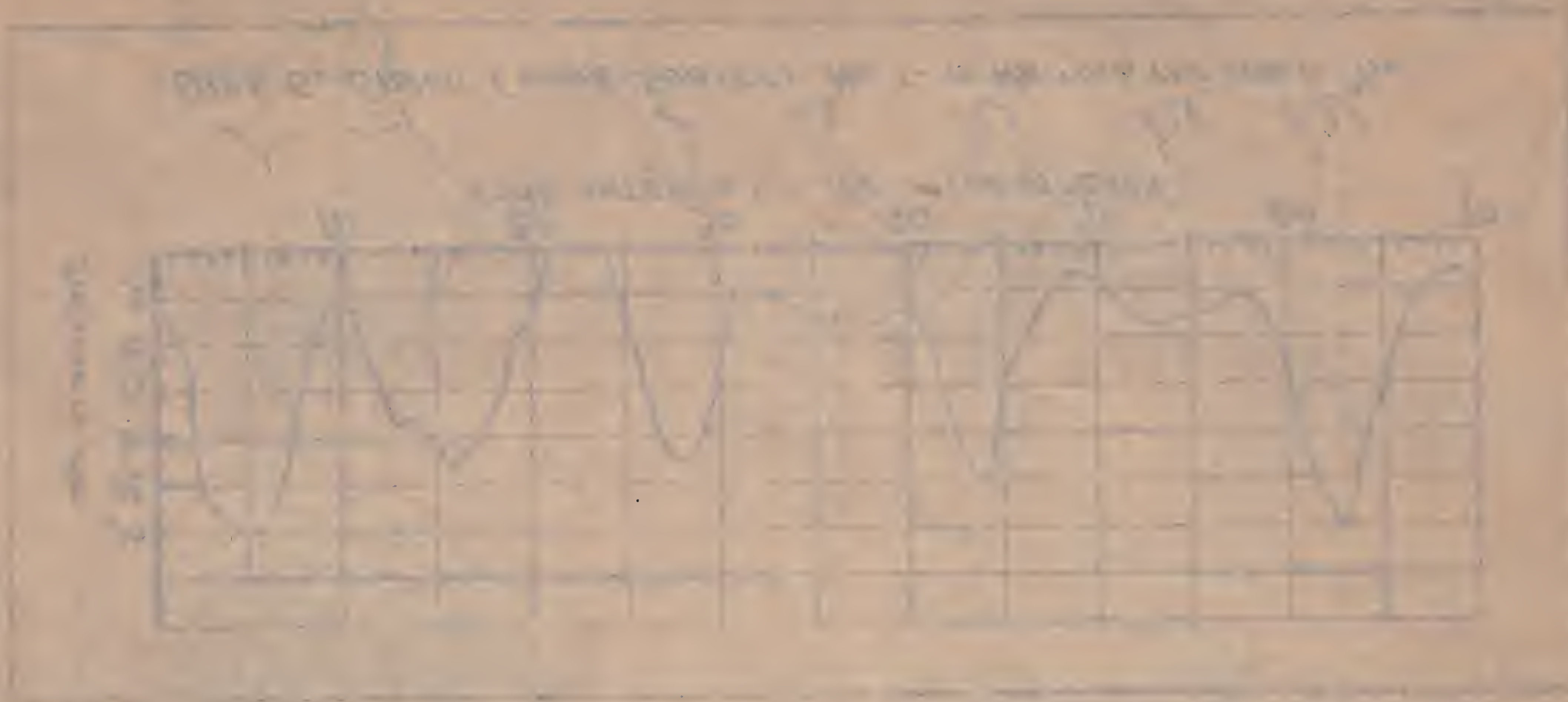
Table 11.

Tabulation of Measures of the Exercise "he" - Record No. 1 H_2

Stroke No.	Time Inter.	Rate of Speed	Stroke Length
I.	1	8	
	2	12	
	3	27	
	4	28¼	
	5	30	
	6	30	
	7	24	
	8	13	
	9	7½	179¾
II.	10	5	
	11	10	
	12	14½	
	13	19	
	14	18	
	15	21	
	16	23	
	17	21	
	18	18	
	19	10	
	20	8	
	21	-	
	22	-	167½
III.	23	-	
	24	-	
	25	8	
	26	13	
	27	21	
	28	23	
	29	20	
	30	12	
	31	4	101
IV.	32	5	
	33	5½	
	34	6½	
	35	8	
	36	8	
	37	7	
	38	8½	
	39	7½	55½
V.	40	7	
	41	9	
	42	16	
	43	22½	
	44	25¼	
	45	14	
	46	11	
	47	6½	
	48	4	
	49	3	118¼
VI.	50	4	
	51	5	
	52	8	
	53	9	
	54	8½	
	55	8	
	56	7½	
	57	6½	
	58	5½	62¼
VII.	59	7½	
	60	15	
	61	21	
	62	27	
	63	30	
	64	22	
	65	16	
	66	8½	
	67	4½	
	68	4	
	69	3	164½
	Total		848½



DIAG 6. SPEED CURVE-SUBJECT No. 1-IN WRITING THE WORD "he".



In most cases the results were graphed for the direct observation of characteristics. In Diagram 6 is shown a graphic representation of the measurements given in Table 11. It should be interpreted in the following manner.

Diagram 6. Speed Curve for writing word "he"

In writing the word "he" this subject required a total of sixty-nine fiftieths of a second, or 1.38 seconds. During the first fiftieth of a second observed, the pen traveled a distance of 8 units, during the second fiftieth 12 units, a rising in speed in the third interval to 27 units. In the fifth and sixth intervals the writer attained a maximum speed of 30 units, and in the tenth period the rate of motion decreased to 5 units, after which came another increment of speed. At the end of the twentieth interval the pen came to a point of rest and remained so for four-fiftieths of a second, etc. etc. When these changes of speed are related to the respective portions of the written form, they become more significant. The graphic curve of speed shows five principal humps, each corresponding to the five longest strokes used in writing the word, while the two shorter strokes are represented in the two lower irregular humps. (Note the related strokes as indicated in heavy lines below.) The rest is now seen to occur at the end of the second stroke (down stroke) in "h".

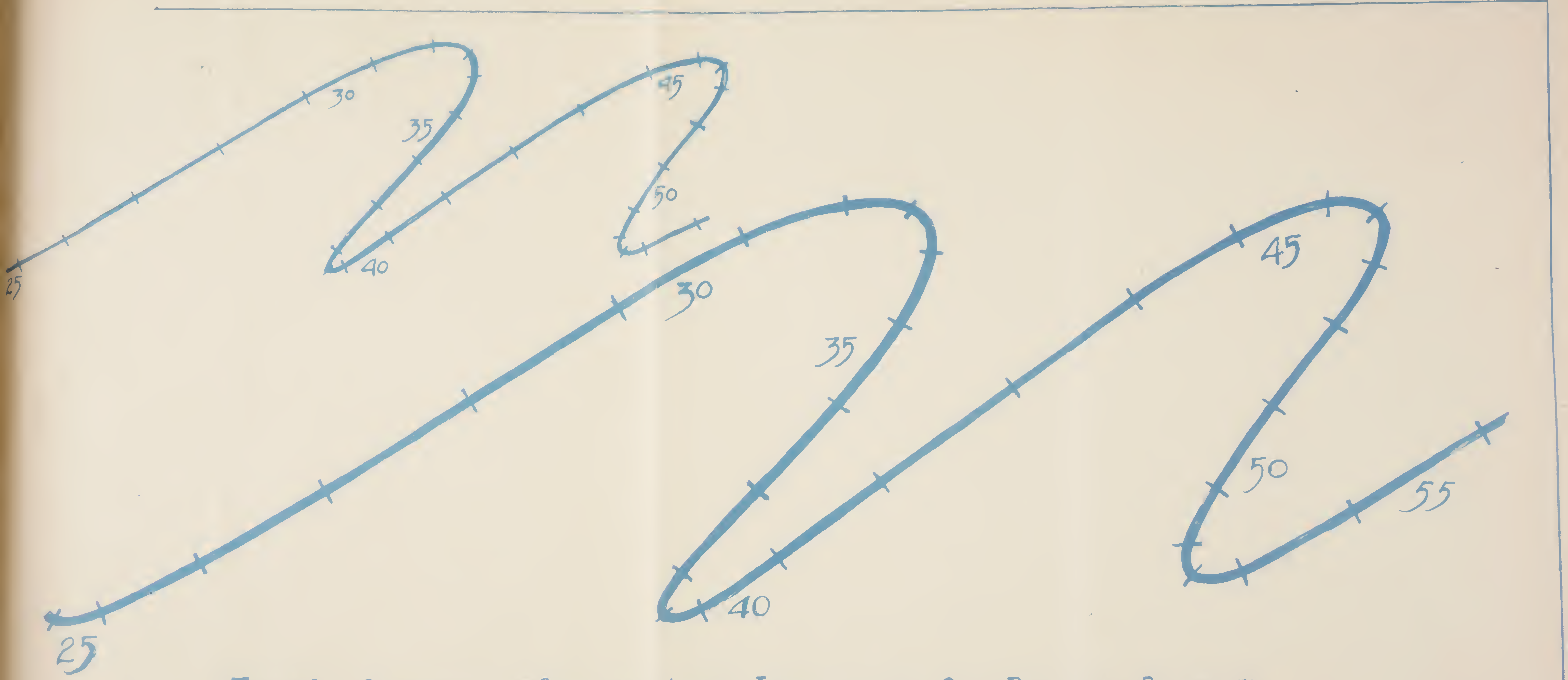


FIG. 12 - COMPARISON OF SMALL AND LARGE IMAGES OF THE SAME RECORD AS PROJECTED FROM DISTANCES OF 3 m AND 5.1 m. RESPECTIVELY AND TRACED TO SHOW RELATIVE SIZES.

The value of the speed curve, drawn so as to connect the summits of the successive measures on the ordinates will be seen later in the process of interpretation (i.e. see p. 101 ff.). Acting on the assumption that there would generally be an even progress of movement in the changes from one speed to another, care was taken that the curve should be slightly rounded rather than angled at the points of change. The scale here shown, i.e., one unit on the abscissa for each fiftieth of a second, and one half unit on the ordinate for each unit of distance covered, was generally adhered to in all analyses. The relative height of the scale was determined aribtrarily, in view of the fact that this ratio seemed to be most favorable to interpretation.

The measures which were made and thus represented, depended however on the absolute degree of enlargement of the projected image. The projection apparatus was first placed at a focal distance of about three meters from the screen so as to give an enlargement of 39 diameters, and the image was marked, measured, and the results graphed. Later a test was made of the same record at a focal distance of 5.1 meters, giving an enlargement of 66 diameters from the film, or about 7.2 diameters from the original writing, the record being similarly analysed. The results were then compared (Figure 12) and (Diagram 7) and were found to give essentially

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Figure 12. Comparison of records as projected and marked from different focal distances

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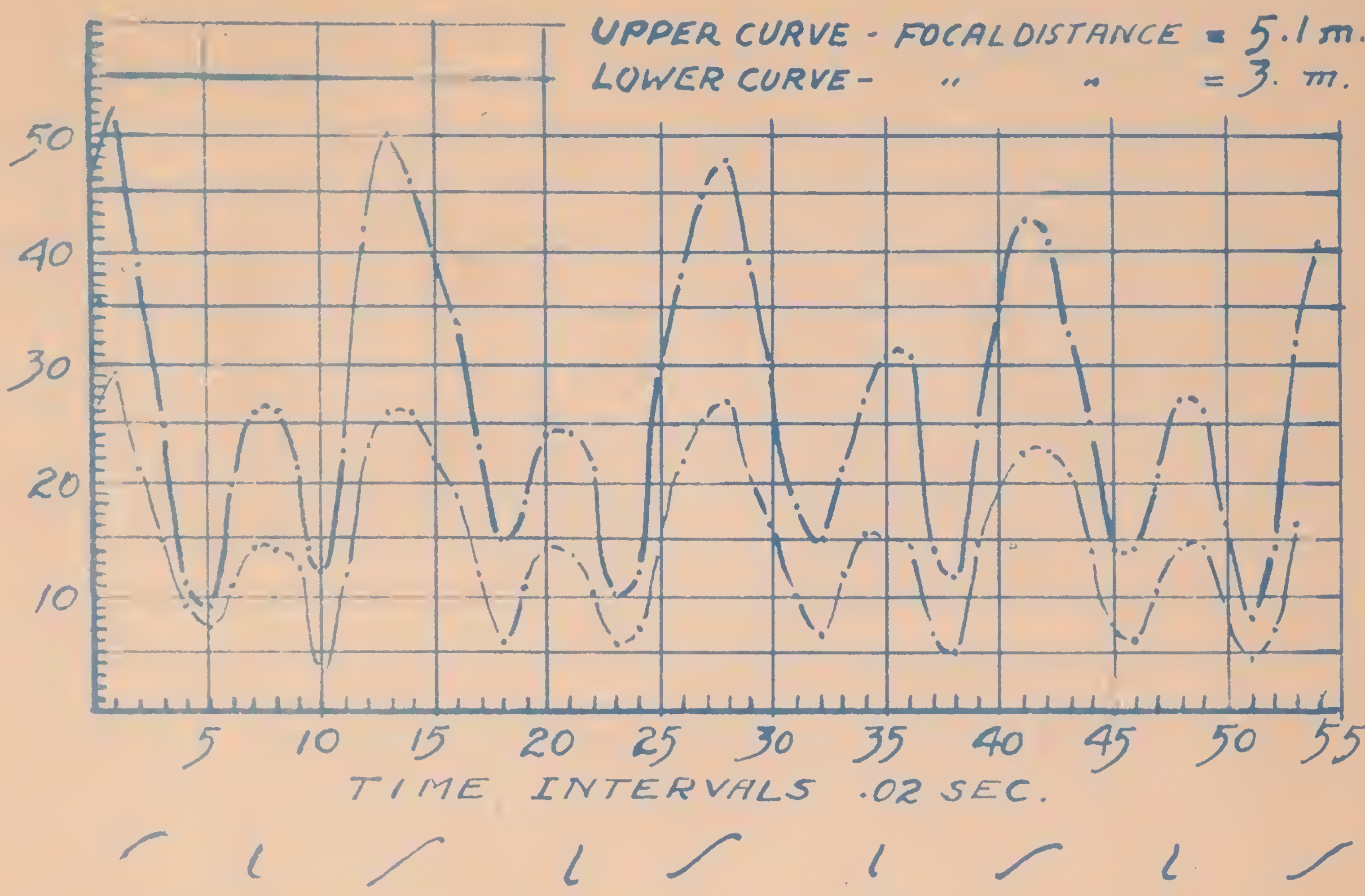

DIAG 7. COMPARISON OF SPEED CURVES FOR RECORDS OF FIG. 12 - PROJECTED AT DIFFERENT FOCAL DISTANCES

Diagram 7. Comparison of speed curves of Records of Figure 12

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identical data, but since the latter gave better opportunity for study and exact measurement the focal distance of 5.1 meters was made the standard.

The reliability of the measuring process was scientifically determined before many records were analyzed, or any results were quoted as authoritative. Two observers, A.G. and P.W., of whom the latter was fairly acquainted with the technique, acted independently in measuring and tabulating a record of large curved strokes. The record as traced and marked by the two observers is shown in Figure 13, parts A and B respectively.

Figure 13. Comparison of records as traced and marked for measure by different observers - A by G, B by W

The measured results, as tabulated in Table 12, show a remarkably small amount of variation. The total length of the written line was found by each to be 1650 m̸ [a] , so there was actually no variation in the total measure. However, there was a total variation unit by unit, of 90 m̸ (45 m̸ plus

[a]The unit of distance will henceforth be represented by the symbol (m̸) and the unit of time by the symbol (s̸), the former meaning a millimeter on the enlarged scale of the image and the latter meaning a fiftieth of a second.

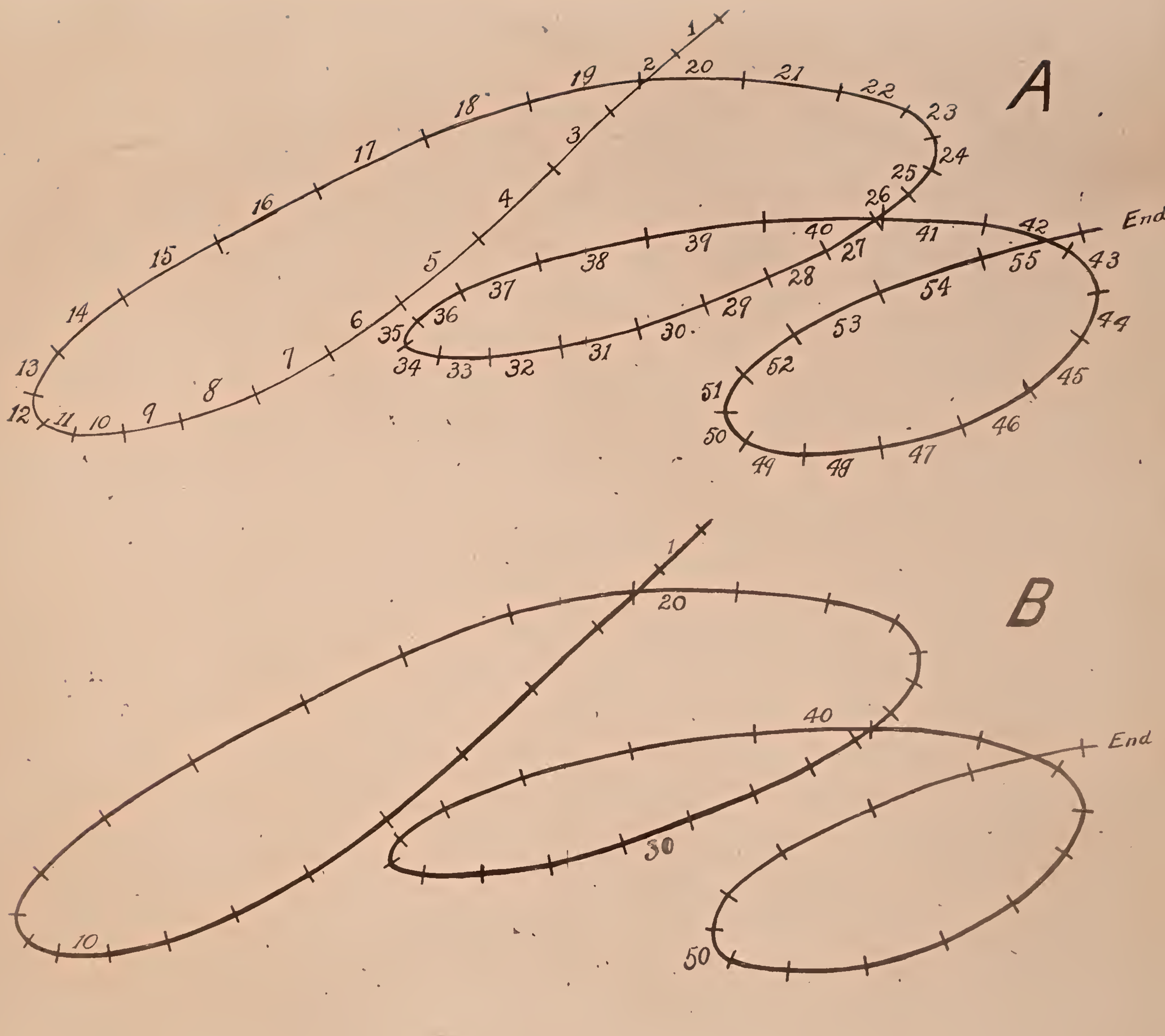
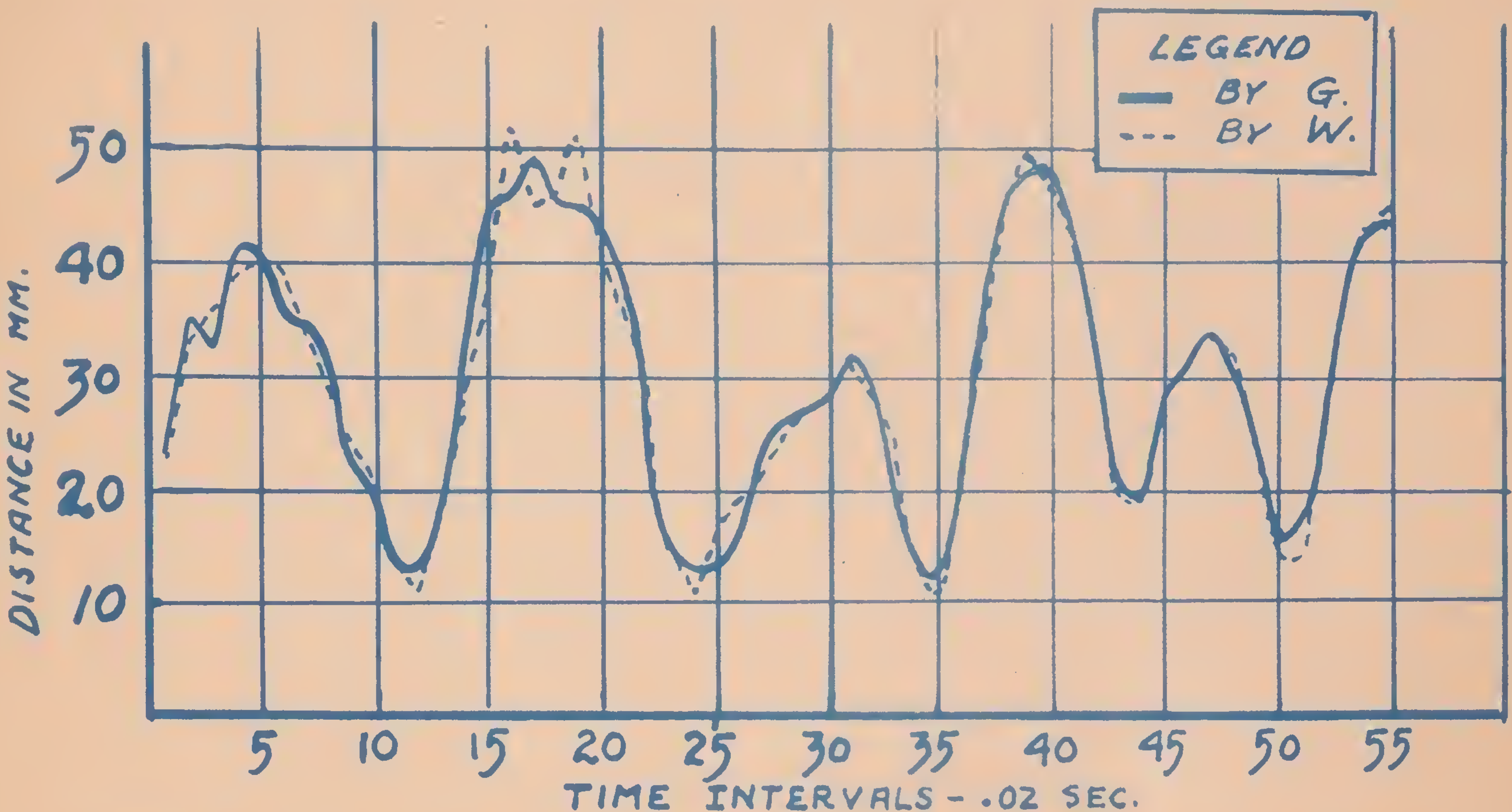


FIG. 13 - COMPARISON OF TRACINGS OF THE SAME RECORD BY TWO OBSERVERS - G. AND W. - WORKING INDEPENDENTLY

and 45 ∮ minus) from each others records, which is 5.4% of the total distance measured. This amounted to 1.7 ∮ for each 30 ∮ which was the average rate for each fiftieth of a second (∮).* The high coefficient of reliability of nearly 95% marks a notable exactness of technique. It is noticeable that the variation was greatest in the longest spaces where the dashes were more attenuated and the midpoints less easily determined. In ordinary writing such high speed is never attained, hence such a source of error is minimized. The comparison of measures as totalled for the strokes shows approximately identical results, with a total variation of about .8%.

Table 12.

Stroke Number	Interv Number	Observer A.G.		Observer P.W.		Var.	
I.	1	23		23		-	-
	2	35		34		1	-
	3	33		36		-	3
	4	41		39		2	-
	5	41		40		1	-
	6	35		39		-	4
	7	35		34		1	-
	8	32		29		3	-
	9	23		24		-	1
	10	20		21		-	1
	11	13	331	13	332		
II.	12	13		11		2	-
	13	19		19		-	-
	14	34		34		-	-
	15	45		37		8	-
	16	45		52		-	7
	17	49		45		4	-
	18	45		46		-	1
	19	45		51		-	6
	20	43		41		2	-
	21	39		36		3	-
	22	28		28		-	-
	23	15		16		-	1
	24	13	433	11	427	2	-
III.	25	13		16		-	3
	26	16		19		-	3
	27	24		21		3	-
	28	26		25		1	-
	29	27		27		-	-
	30	28		29		-	1
	31	32		31		1	-
	32	29		28		1	-
	33	21		24		-	3
	34	14	230	14	234		
IV.	35	12		11		1	-
	36	20		22		-	2
	37	35		34		1	-
	38	45		45		-	-
	39	48		50		-	2
	40	48		47		1	-
	41	41		42		-	1
	42	35		34		1	-
	43	21		20		1	-
	44	19	324	19	324		
V.	45	29		29		-	-
	46	31		31		-	-
	47	34		34		-	-
	48	31		32		-	1
	49	25		24		1	-
	50	~~15~~	~~165~~	~~14~~	~~164~~		
VI.	51	17		14		3	-
	52	26		27		-	1
	53	38		40		-	2
	54	43		43		-	-
	55	43		45		-	2
Total		1650		1650		45	45



DIAG. 8 - COMPARISON OF MEASUREMENTS OF THE SAME RECORD BY TWO OBSERVERS

The speed curves of the two sets of measures are remarkably in agreement for purposes of interpretation.

Diagram 8. Comparison of Measurements of Two Observers

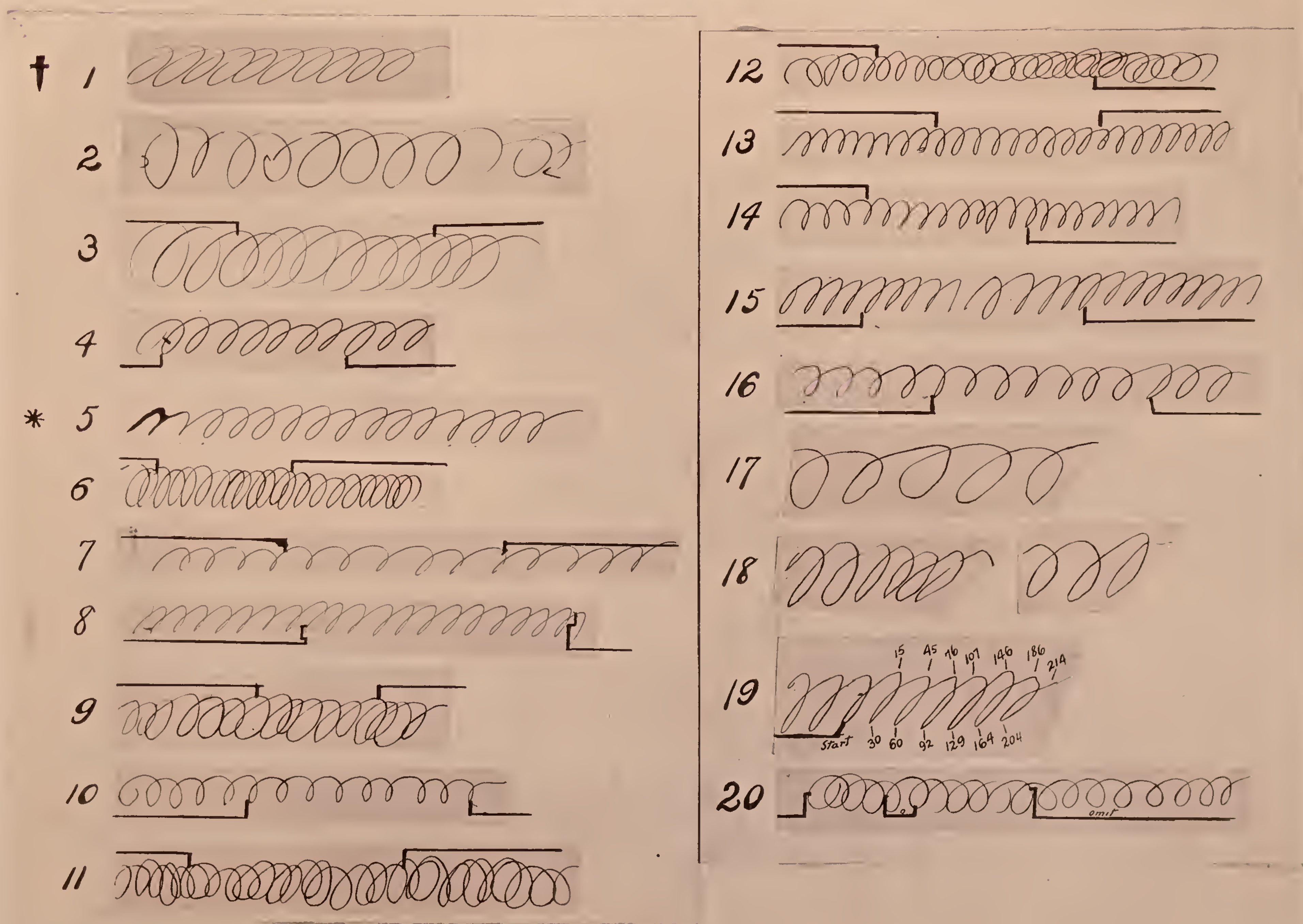
RESULTS

The findings of this study cannot, in any sense, be declared exhaustive. The primary emphasis was, of necessity, placed on the development of requisite apparatus and method, yet many records were analyzed and data assembled that point the way to quite definite conclusions at certain points. The method used has proved to be very efficient and should be further made use of, under rigid controls, to authoritatively determine the solution of the many problems in the field of handwriting which may thereby be dealt with.

The handwriting movement of 20 different subjects was here investigated and photographic records secured and analyzed for each one. The subjects were distributed as follows. Seven were children, ranging from 7 to 16 years of age. Six were poor adult writers and seven were good adult writers, as judged by the degree of co-ordination chiefly.

Class		Serial Number
Children		13 through 19
Adults	(Poor Writers	2,4,6,9,11,12
	(Good Writers	1,3,5,7,8,10,20

PLATE I



REPRODUCTION OF INDIRECT OVALS AS WRITTEN FOR RECORD BY THE VARIOUS SUBJECTS

Each subject wrote for record a running indirect oval, and the majority then wrote the sentence, "Then he wakes Lucy from sleep," so that a study might be made of a simple repetetive form as well as a sample of characteristic penmanship.

Organization

Units of Movement.

It has been clearly noted by Freeman* that the better writers tend to divide their writing into definite units or strokes, with a moment of slowing down of the speed which serves to distinctly differentiate the successive strokes, while the poorer writers usually show no such regular type of organization. The evidence noted on this point in this investigation is merely corroborative.

In Plate I is given the photographic reproduction of the indirect oval as written by each of the 20 subjects. In

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Plate One. Samples of Indirect Ovals as Made for Record by Subjects

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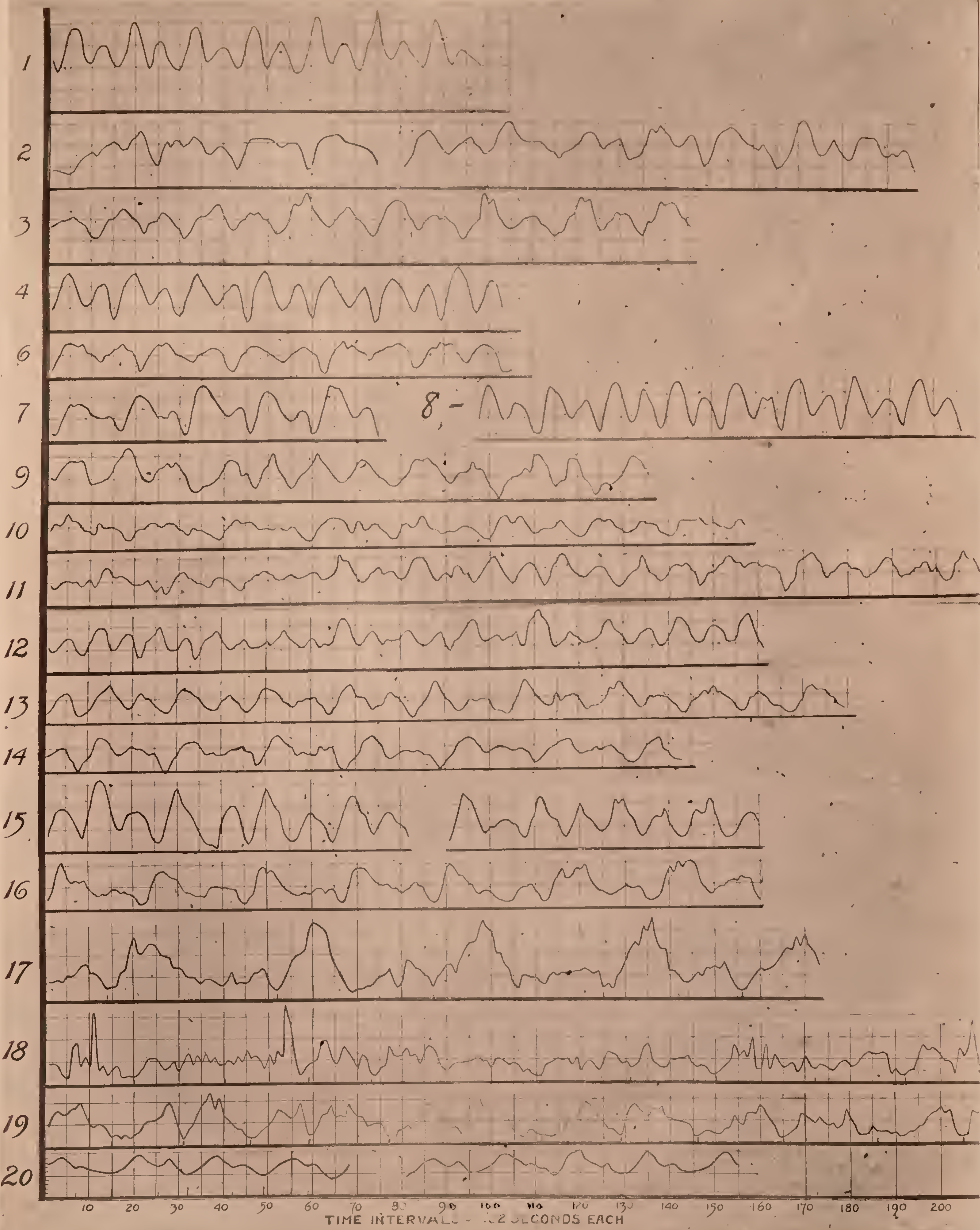
each case, that part of the original written record which was not photographically recorded is indicated by heavy horizontal lines, either above or below, and terminating so as to locate the point at which the record was begun or ended. Subject

*Freeman, F.N. The Handwriting Movement. Educ.Mon.#11, p.17.

PLATE II



SPEED CURVES FOR SUBJECTS IN WRITING INDIRECT OVALS

No. 5 made no photographic record for this exercise. In the case of Subject No. 1, although the photographic record was gotten, the original written record was destroyed and a sample of typical writing substituted. Plate II exhibits the speed curves for each subject in performing the exercise shown in Plate I. The results are here grouped, not for the purpose of detailed measurement, but for ready comparison.

Plate II.

As one surveys the records of Plate II one is struck with the great variety of speed curves as to form. In the following table (Table 13) the subjects are classified as to their typ of organization in this exercise, and also as to their degree of penmanship ability.

Table 13.
Relation between Type of Stroke Organization and Quality of Penmanship.

Type of Organization	Number of the Subject: Adults		Children	
	Good	Poor	Good	Poor
1. Clear differentiation of strokes - speed emphasis on up-stroke	1,3,7 8	4	13,14, 15	
2. Differentiation with equal speed emphasis		6,9		19
3. Recognition of unit strokes but no definite limits	10.20	2,11		16,17
4. Variable		12		
5. No differentiation				18

FIG 14 - SAMPLE OF USUAL PENMANSHIP OF SUBJ. #2

It is noteworthy that the good and poor writers in the first group of the table stand in the ratio of 7 to 1, the only poor writer being No. 4. And when one examines the penmanship of this writer, it is found that this writer's chief fault lies, not in neglect of stroke values, but in lack of appreciation of the standard forms. The most marked characteristic of the members of this group is in the giving of full value to each stroke of the exercise. Most of them write in a forward slant, though No. 14 shows a great deal of variation.

None of the second group is a good writer. The two adults habitually slur over the strokes in their writing and none of the group seems to have differentiated between up and down strokes as to requisite length or speed emphasis.

Of group three, No. 10 and No. 20 are good writers. It is notable that these subjects give an open, vertical form to the ovals and make less differentiation than would be the case with a slanting, compact curve. Subject 2 of this group, a sample of whose writing is here given in Figure 14, is a smooth, fluent writer who makes good use of arm movement, but who seems unable to organize his strokes definitely so as to form connected, yet separable units. In this illustration it is notable that the down stroke and the up stroke are not united in his habit, so that his pen is even raised from the

Figure 14. Sample of Writing of Subject No. 2.

paper at the end of a down stroke in many cases. Subjects 16 and 17 are uncontrolled writers who have not yet developed habits of differentiation.

Subject 12 is a rapid, impetuous, backhand writer, who at times gives evidence of a definite plan of organization for a few strokes, then on other strokes may follow no definite, coherent plan.

Subject No. 18 is the youngest child writer, 7 years of age, and as yet gives no evidence of having achieved any recognition whatever of stroke organization.

The evidence furnished from this small group is consistent with the conclusions of Freeman above noted. It must be understood, however, that poor writing, as here defined, is one of formal emphasis, having to do with the organization of the strokes so as to conform to definite demands as to what the form of the letters shall be, but in no sense relating to elements of co-ordination which we shall next consider.

Steadiness in the Rate of Movement.

There is a marked difference between the speed curves (Plate II)of the various subjects in the evenness of progression of the line representing speed changes. In some cases the curve shows very frequent changes which indicate decided fluctuations in the rate of movement, while in other cases the progress is quite steady showing only the regular rise and fall of the rates of movement at the middle and end of successive strokes.

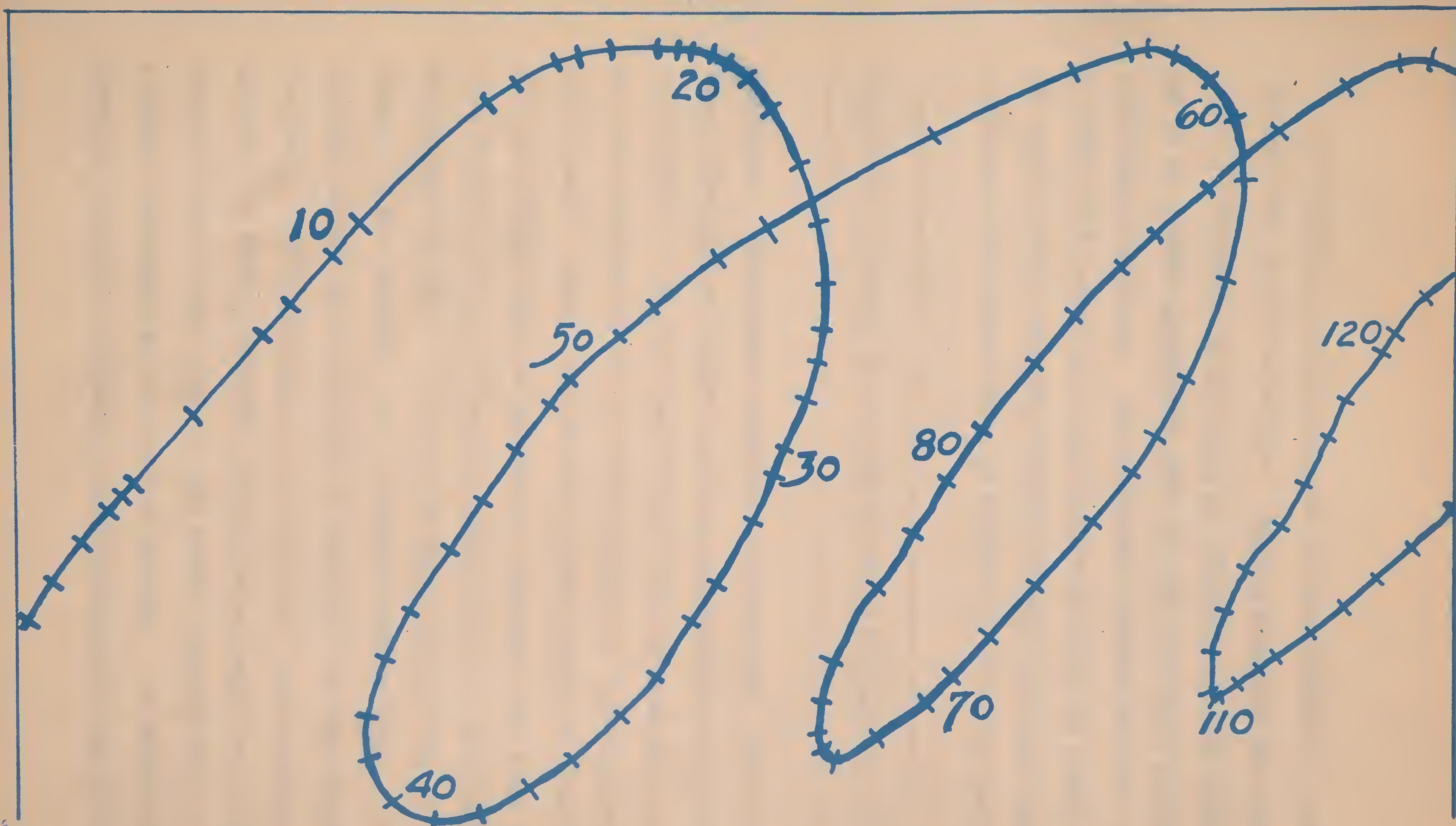


FIG. 15. TRACING OF IMAGE OF RECORD OF CHILD SUBJECT NO. 18

As a most noteworthy example of the former the record of Subject No. 18 may be cited. Such a frequent and characteristic fluctuation in the rate of movement obtains throughout as to be almost incredible were it not sustained by careful scientific evidence. The original exercise of this subject, a child of 7 years, on which the speed curve is based, is shown in Plate I, and a careful tracing of the projected image is reproduced in reduced form in Figure 15, so as to permit of

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Figure 15. Tracing of Writing of Child Subject No. 18

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analysis. The spaces between the cross bars represent the time interval, as before noted and explained, of a fiftieth of a second. As one observes the line of writing one is struck by the irregularity in the distribution of time intervals throughout. There is apparent no one moment of maximum speed in any stroke, which is gradually approached and then gradually departed from; in fact, a higher rate of speed may suddenly succeed one of slow rate or vice versa, without any transition, as for example, in the second upward stroke. No two strokes of any kind are alike in the order of the rates of progress. In some cases, as in the first down stroke, the movement is fairly uniform, rising to no height of speed, in contrast with those, such as the second down stroke, which show a marked variation in the rate of motion. In every stroke there is abundant evidence of incoordination in the more or less

abrupt changes in the direction of movement, but these seem to be quite independent of the rate of movement. The other child records, No. 17 and No. 19, are in general similar to this one, though less extreme in the degree of coordination, probably due to the greater age of the children.

The form of the oval as made by the child subject No. 18 is not highly objectionable in its general outlines, in fact some of the curves approach quite well the standard requirement, but closer analysis reveals the waverings in the line. Manifestly this child subject has acquired no control of the muscles used in the writing process so there is any freedom of movement. The small variations in speed and form are doubtless due quite directly to the lack of nerve steadiness. The writing is, for the most part, slowly drawn. The child does not in any sense recognize the exercise as divided into strokes which are to be treated as separate, definite units of movement. It may be that frictions of the pen on the writing surface, as well as muscular inhibitions and uncontrolled movements, have united to introduce elements into the writing process which prevent the establishing of any relation between the direction or extent of movement and the speed with which the movement is made. In coordination of this type is clearly recognizable.

Another type of incoordination is that illustrated in the case of Subject No. 11, a sample of whose writing and the speed curve for the same are shown in Plates I and II respectively. The tracing of the enlarged image of this sample is shown in

FIG. 16 - TRACING OF IMAGE OF WRITTEN RECORD OF SUBJECT No. 11

Figure 16. In this instance the subjects shows markedly less tendency to variation in direction, nevertheless furnishes many evidences of abrupt changes which are not in the form of a regular curve being constructed, or harmonious to it. It is notable that the changes in direction are regularly accom-

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Figure 16. Tracing of Writing of Adult Subject No. 11

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panied with changes in speed, so that abrupt changes reduce the rate of motion while strokes which are longer and having an even curve are made with an even increase of speed to the midpoint, followed by a decrease.

This subject has evidently established a form of control that was quite lacking in the case of Subject No. 18. He has established a freedom of movement which generally insures a correspondence of speed and direction of movement. His difficulties are primarily mechanical ones in the sense of not being able to coordinate the activity of the fingers and arm in such a way as to produce a uniform and well constructed product.

The first type of incoordination is characteristic of the writing of children who are beginning to write, or of some adults who are for the first time using an unexercised muscle. This second type is found among the more advanced child writers and also among the poor adult writers. This type of incoordination can be clearly noted by the characteristic breaking of curved forms into angular sections, though the line of writ-

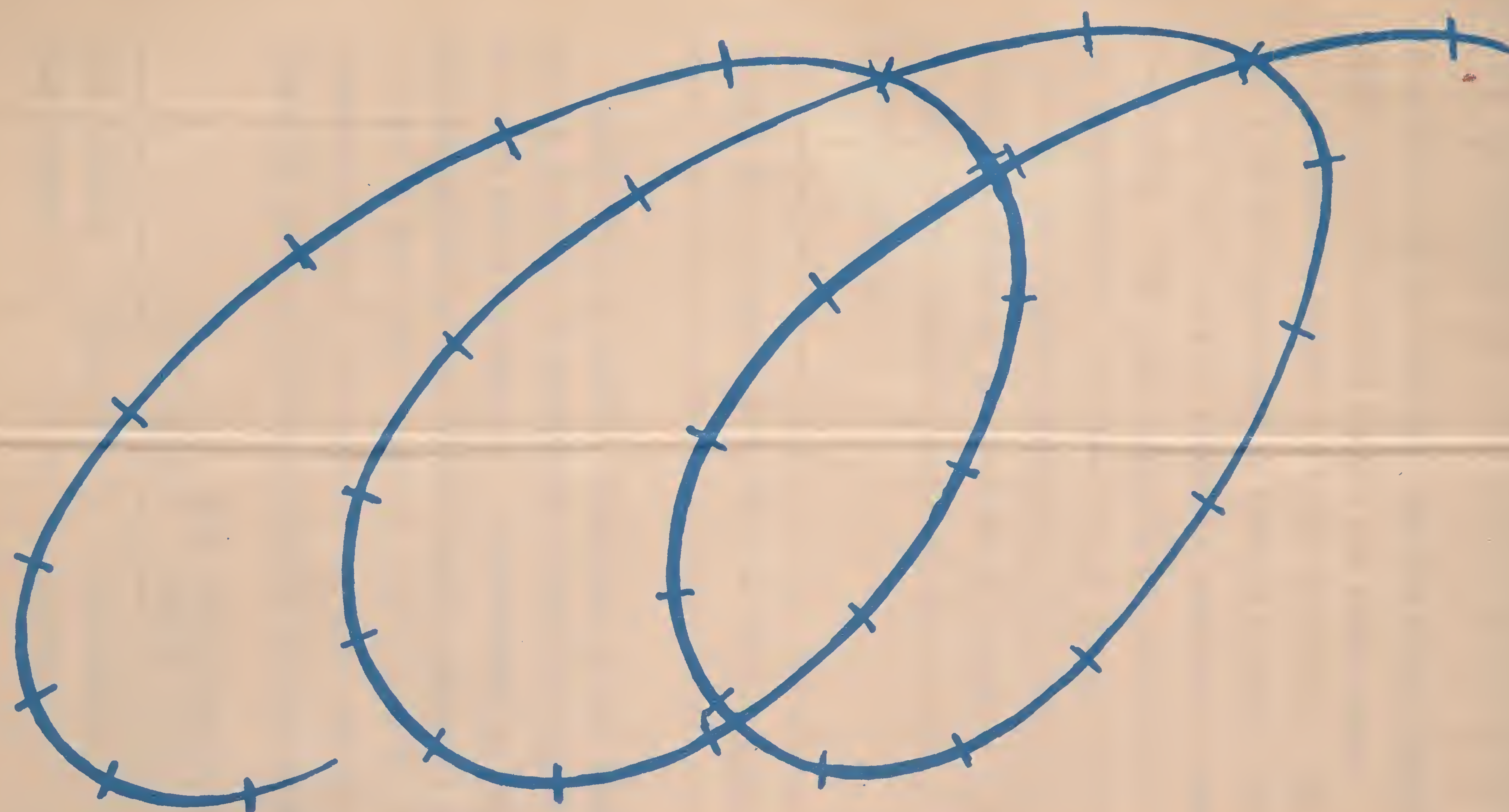

FIG. 17 - TRACING OF PART OF IMAGE OF RECORD BY SUBJECT NO. 1

ing itself is not wavering and the speed progress will be quite well controlled within any such section.

In marked contrast to these exhibits is that of Subject No. 1 in the same exercise (Plates I and II and Figure 17). In this case there is a general tendency to round all curves regularly. There is, throughout the exercise, no evidence of incoordination of either of the above mentioned types. The definite and regular progression of movement is quite marked. This is a sample of writing and of record of a mature subject of good writing ability and represents a goal of achievement in this respect.

Figure 17. Tracing of Writing of Adult Subject No. 1

There are, of course, gradations of all three of these types, and as well, an intermingling of them, but the written product may give clear evidence of a predominance of one over the other in some cases, as well as the marked existence of one or both. A study of the written records (Plate I) shows the following classification of the subjects and this classification is corroborated by the evidence furnished by the speed curves (Plate II).

	Type as to Coordination		
	Wavering Line	Angled Curves	Even Curves
Poor Writers	17,18,19	9,11,13,16	2,4,6
Good Writers		10,13,14	1,3,7,8,15, 20

It is notable that one good adult writer and two child writers of good quality fall among those who do not make well rounded curves, but their defect is small in comparison and is not evident to casual inspection because of other excellence of form. In general, the better writers are characterized by a higher degree of coordination.

Distribution of Speed Within the Stroke.

It has been clearly noted by Freeman and others that the better writers tend to place the greatest speed at the middle of the stroke, with a gradual approach and falling away from this speed. Such a tendency is, of course, modified in the course of actual writing by the nature of the preceding and following strokes, and so is best recognized and analyzed in the repetitive exercise of the running oval. In writing of this type the speed curve should show a characteristic distribution of speed; i.e., a regular increase of speed to a maximum then a regular falling away to a low speed somewhat as at the beginning of the stroke, the form of distribution being fairly well balanced about the point of maximum speed. If we examine the records of Plate II for those subjects who make a clear distinction between up and down strokes (#1, 3, 4, 6, 7, 8, 9, 13, 14, 15, 19) a great difference is found in this respect for the different individuals.

Analysis of the curve for Subject No. 1 shows the strokes to be quite regular. In the 2nd, 3rd, 4th and next to the last strokes there is evidence of a skewing toward the left,

indicating a more rapid accumulation of speed in the beginning of the stroke than there is a slowing down at the end.

In the case of Subject No. 3 comparatively few strokes show this even distribution of speed. The majority of the strokes show some irregularity in the approach to and falling away from the moment of maximum speed, and quite often there are two modes of speed in a stroke. Few of the curves for any stroke are notably skewed, however, and though there is some evidence of irregular progression in the original writing (Plate I) the ovals are, as a rule, made quite smoothly and regularly. One of the best examples of the regular curve is seem in the case of Subject No. 8 (Plate 11). Curves for strokes 5, 7, 8, 9 and 13 are models of symmetry, although most of the others are slightly skewed to the left or right. Subject No. 7 tends to skew the curved records to the left on the up strokes by placing the maximum speed early in the stroke, and to the right in the down strokes by slowing down quite suddenly. Consistent with this fact the top curves in the ovals are largely rounded, and the bottom curves quite narrow, the pen moving quite rapidly in the first case and quite slowly in the latter case. Subject No. 16 also has this habit quite strongly fixed and their written records (Plate I) show general similarities.

The child subject No. 17 already shows quite a tendency to symmetry of movement in the main up stroke which he has under fair control, but the incoordination destroys the form of the curve in every case. Subject No. 19 has not attained any

control of the symmetrical placement of speed within the stroke, nor have some adult subjects, as No. 11.

In the case of nearly all subjects there can be found indications of the symmetrical distribution of speed on isolated strokes, but, unless there is a general tendency to this end, so that the majority of the strokes are of this character, the writer cannot be said to have achieved the mastery of this element.

To what extent this is a desirable feature, or to what degree specific practise is to be recommended for itsaccomplishment are questions which cannot be determined by this investigation. The better writers unmistakably show an emphasis on this characteristic.

Possibly this characteristic, when present, functions in such a way as to contribute special, beneficial features to the writing process. Just what these features are can best be appreciated by an intensive study of the penmanship produced under various conditions.

To cite specific instances subjects No. 6 and No. 9 are defective writers chiefly because of poor distribution of speed; the former places the maximum speed too early in the stroke with the result that the strokes are thrown out of shape, with evidence of strokes too long, curves that are too rounded, etc. The latter, in many cases stops too suddenly, with the result that his writing is generally more angular, with small recognition of terminal curves. In both cases the writing is thrown out of alinement. (See Plate III, p.115)

In Sample 1 is shown the writing of one who has very good control in this respect and regularly distributes the speed of the stroke symmetrically. Reverses, angles, curves, letter forms and spaces are all quite well cared for. His regularity has already been noted in the analysis of speed curves (p. 106).

In general it is difficult to find any writer who is exclusively at fault in placing the maximum speed either too early or too late in the stroke, or to find one who is entirely devoid of either of these characteristics. The form of some strokes used in writing probably necessitates so much distribution. But where they may be counted as defects they are clearly recognizable, and when either or both occur to such an extent as to mar the written product, they require specific attention.

It is evident that this defect cannot be easily identified, as distinct from errors of perception. However, if specific training in the perception of forms does not result in improvement in these characteristics, although the form of the latter may be changed, or improved, it is well to look to the movement as the more probable cause. Furthermore, perceptual error is not apt to characterize a person's entire writing. Some forms will be well registered, and effected, while others will be notably defective. But when the motor elements are at fault, the whole writing process is affected throughout, and any or all forms will suffer. A person may produce defective forms and yet give evidence of a symmetrical movement within the forms which he produces. In this case a perceptual error is likely.

The problem of organization of movement is here found to be directly significant for such elements as steadiness of line, rounding of curves, construction of angles or reversals at the end of strokes, length of strokes, spaces between letters, alinement, etc., and is therefore significant especially in relation to letter form. There is the pertinent question whether the type of movement is the cause, or whether it is the effect of an attempt to adapt oneself to the form as imaged in consciousness. In every case the individual writing should be analysed, as indicated above, so as to isolate and deal with these two factors and note to what an extent either or both are present or predominant.

Natural Rhythm.

The presence or absence of simple temporal rhythm may be noted in the case of each subject, first in the simple repetitive forms, as the running oval, and secondly, in ordinary writing, by noting the time required by the subject in making successive strokes, and computing the average or percent deviation of these periods. In the exercise with the oval the comparison is easily made, as all up strokes and down strokes are easily identifiable where the writer has differentiated between them. The union of the up and down stroke may also be considered a unit, the up stroke usually receiving the rhythmic beat, and these units may be compared in the same way.

In Table 14 are presented the figures showing the time spent by each subject on each stroke (up or down) and each pair of strokes (total) in performing the exercise indicated in Plate

1. The same data are represented graphically on the horizontal scales in Plate II, but not in comparable form.

Table 14

Temporal Rhythm in Spontaneous Writing of Indirect Running Oval.

		Time per stroke .. 50ths of a second														Variation	
Indiv.	Unit.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10	11	12	Tot.	Ave.	Tot.	PerCent
1.	Up	8	7	7	7	8	7	7						51	7.3	2.9	5.7
	Down	6	6	7	7	6	7	7						46	6.6	3.4	7.4
	Tot.	14	13	14	14	14	14	14						97	13.9	1.5	1.5
2.	Up	12	12	10	10	10	10	10	11	12	10	9		116	10.5	9.5	8.2
	Down	8	6	6	6	8	7	6	6	4	6	6		69	6.3	8.5	12.3
	Tot.	20	18	16	16	18	17	16	17	16	16	15		185	16.8	11.8	6.4
3.	Up	-	11	11	12	10	11	11	11					77	11.0	2.0	2.6
	Down	10	9	10	10	10	10	9	-					68	9.7	2.9	4.3
	Tot.	-	20	21	22	20	21	20	-					124	20.7	4.0	3.2
4.	Up	8	8	8	8	8	9	8						57	8.1	1.5	2.6
	Down	6	7	7	7	6	6	6						45	6.4	3.4	7.6
	Tot.	14	15	15	15	14	15	14						102	14.6	3.4	3.3
6.	Up	11	12	11	10	11								55	11.0	2.0	3.6
	Down	9	9	10	10	8								46	9.2	3.2	7.0
	Tot	20	21	21	20	19								101	20.2	3.2	3.1
7.	Up	10	10	10	9	10								49	9.8	1.6	3.3
	Down	5	4	5	5	5								24	4.8	1.6	6.7
	Tot.	15	14	15	14	15								73	14.6	2.4	3.3
8.	Up	7	8	7	7	8	7	7	7					58	7.2	2.8	4.8
	Down	7	6	7	6	6	6	7	6					51	6.5	4.0	7.8
	Tot.	14	14	14	13	14	13	14	13					109	13.7	3.6	3.3
9.	Up	-	13	14	12	13	13							65	13.0	2.0	3.1
	Down	8	10	8	11	11	9							57	9.5	7.0	12.3
	Tot.	8	23	22	23	24	22							128	24.8	3.2	2.8
10.	Up	10	13	12	13	13	12	11	13					97	12.1	7.0	7.2
	Down	8	7	8	7	7	9	10						56	8.0	6.0	10,7
	Tot.	18	20	20	20	20	21	21						140	20.0	4.0	2.8
11.	Up	9	10	10	-	10	8	9	10	9	10	9	8	102	8.3	7.3	7.1
	Down	9	6	7	-	9	8	7	8	9	9	9	10	91	8.3	10.7	11.7
	Tot.	18	16	17	18	19	16	16	18	18	19	18	18	211	17.6	12.5	5.9

(Table 14 continued)

12.	Up	7	8	8	-	9	9	8	8	9	9	75	8.3	5.3	7.1
	Down	6	5	5	-	5	6	8	7	7	7	56	6.2	8.2	14.6
	Tot.	13	13	13	14	14	15	16	15	16	16	146	14.6	10.8	7.4
13.	Up	-	11	10	10	10	10	10	12	13	12	98	10.9	8.9	9.0
	Down	7	9	8	8	9	11	8	9	10		79	8.8	7.2	9.0
	Tot.	-	20	18	18	19	21	18	21	23		158	19.8	12.0	7.6
14.	Up	9	13	11	11	10	11	11				76	10.9	5.3	7.0
	Down	10	8	8	11	11	11					59	9.8	7.4	12.5
	Tot.	19	21	19	22	21	22	-				124	20.7	6.6	5.3
15.	Up	-	9	13	10	10	8	9	9	10		78	9.7	8.0	10.0
	Down	8	8	7	9	8	9	8	9	-		66	8.2	4.4	6.7
	Tot.	0	17	20	19	18	17	17	18	-		126	18.0	6.0	4.8
16.	Up	11	14	12	13	17	15	13				95	13.6	10.6	11.2
	Down	10	9	10	7	8	9	11				64	9.1	7.1	11.1
	Tot.	21	23	22	20	25	24	24				159	22.7	10.5	6.6
17.	Up and down strokes inseparable														
	Tot.	38	35	38	30							141	35.3	11.0	9.9
18.	Up	20	18	18	21	23	22	19				141	20,1	10.9	7.7
	Down	20	14	20	18	20	18	22				132	18.9	8.1	6.1
	Tot.	40	32	38	39	43	40	41				273	39.0	16.0	5.8
19.	Up	17	15	18	20	19	24					113	18.8	13.0	11.5
	Down	14	14	14	16	17	17					92	15.3	8.0	8.7
	Tot.	31	29	32	36	36	41					205	34.1	21.0	10.2
20.	Up	-	10	10	10	10	12	11	10			73.	10.4	4.2	5.8
	Down	8	7	7	6	6	6	4	5			49	6.1	7.2	14.7
	Tot.	-	17	17	16	16	18	15	15			114	16.3	6.3	5.5

Supplement to Table 14

1A.	Up	-	7	7	7	7	8	7	7			50	7.14	1.7	3.4
	Down	7	6	7	7	6	7	7				47	6.7	2.9	6.0
	Tot.	-	13	14	14	13	15	14				83	13.8	3.4	4.0
1B.	Up	9	7	8	8	8	8	8	7	8		71	7.9	3.5	5.0
	Down	6	7	7	7	6	6	6	7	6		64	6.4	4.4	6.9
	Tot.	15	14	15	15	14	14	14	14	14		135	14.3	3.9	2.9
20.	Up and down strokes not separable														
	Tot.	18	14	17	16	17	16					98	16.3	4.6	6.1

The data of this table, although by no means complete for a comprehensive study of any of the individuals, reveals some interesting facts.

In every case where the up and down strokes are clearly differentiated, more time was required for the up stroke than for the down stroke. The amount of difference varies from over 100% in the case of subject No. 7 to less than 6% in the case of No. 18. It is noticeable to casual inspection that the up stroke in the running oval is usually much longer than the down stroke and one may infer as is shown to be the case (page 127) that the greater time is due to the greater length of stroke.

The good adult writers on the whole show less variation from their average length of time than do the poor writers. The following tabulation makes this clear:

	Ave. Per Cent of Var. Up Stroke	Down Stroke	Total
Good writers: 1,3,7,8,10,20	4.9	8.6	3.2
Poor Writers: 2,4,6,9,11,12	5.4	10.9	4.9

No conclusion can be drawn regarding individual cases, however, as some of the very poor writers show much better rhythm than the good writers, on the whole.

The children, although in some cases manifesting a high degree of rhythm as compared with some adults, are on the whole poor in this respect, their average per cent variation being 7.17. There is evidence of a rhythmic tendency, even among the youngest subjects, as No. 18, where the form of the speed curve would not lead one to suspect any such temporal regularity.

No clear differentiation can be made between the two adult groups on the basis of speed, but there is a distinct difference between the time taken by adults and that taken by children in the respective strokes. In the combination of the up and down strokes the range of adult time lies between 13.7 and 24.8 ø, with an average of 17.3 ø, while the range for children is from 18 s/ to 39 ø, with an average of 27.1. This comparatively low speed of children was already noted in the previous experiment (p. 42).

Although there is no perfect correlation between rhythm in this exercise and speed control as manifested in the speed curves (Plate II) those with high degree of rhythm seem to have the best type of speed progress. For example, Subjects 1, 4, 7, 8 and 15, with an average of 3.3 per cent variation, exhibit fewer reversals from high to low speed, and vice versa, while the child subjects 16, 17, 18 and adults 11 and 12 have about the greatest number of speed reversals and also their variation is much greater. However, there are exceptions: #9 and #10 showing many speed reversals, yet showing the low variation of 2.8 per cent each, while No. 20 with few speed reversals exhibits a much higher variation.

The Rhythm of the Written Word.

The study of the writing process as shown in construction of selected passages, carried on along lines similar to that just described, should reveal to what extent temporal rhythm obtains in ordinary writing, which is comparatively quite complex in

PLATE III

1 he wakes Lucy from sleep.

3 Then he wakes Lucy from slee[illegible]

4 Then he wakes Lucy from sleep.

5 hen he wakes Lucy from sleep

6 then he wakes Lucy from sleep

7 Then he wakes Lucy from sleep.

9 Then he wakes Lucy from sleep

10 Then he wakes Lucy from sleep

11 Then he wakes Lucy from sleep.

12 Then he wakes Lucy from sleep

13 Then he wakes Lucy from sleep

14 Then he wakes Lucy from sleep

15 Then he wakes Lucy from sleep

16 Then he Wakes Lucy from sleep.

17 hen he wakes Lucy from sleep

20 Then he wakes Lucy from sleep

SAMPLES OF PENMANSHIP OF THE SUBJECTS AS WRITTEN FOR RECORD

structure. Not all of the samples of writing or illustrations of speed curves can be here presented, but enough typical examples will be given to show the significance of the results. Plate III shows the repoduction of the original writing of the various subjects of this exercise.

Plate III. Samples of Penmanship of the Subjects as Written for Record

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The simplest word, which was written by 15 of the 20 subjects, was "he." This was chosen for preliminary analysis because of the quite simple succession of strokes, 7 in all in the complete form. Opportunity is given to compare the strokes of various lengths, to note the variation of time as affected by length and also to compare the similar influence of form.

The rhythmic beat on this word, according to standard systems of counting, should fall on the first, third, fifth, and seventh strokes. This would presuppose that succeeding pairs of strokes (up and down) are made in corresponding lenghhs of time. The question arises, do writers in general, consciously or unconsciously, provide for such a regularity of beat, or so equalize naturally the successive strokes or pairs of strokes? Furthermore, do the good writers show greater rhythmic appreciation and skill in this respect than do the poor writers?

The analytical study of this exercise is collected in the data of Table 15, the per cent variation being shown for both

individual strokes and pairs of strokes. In the last pair of strokes (d) the seventh stroke is united with the next stroke made after lifting the pen from the paper in transit to the next word "wakes". The variation, whether considered in the singled or paired strokes, is far greater than was the case in the exercise with the running oval. The consideration of the strokes in pairs does not show rhythm markedly superior to that of the single strokes.

Table 15
Comparative Time in % Spent by Each Subject in Each Stroke and Pair of Strokes in Writing the Word "he".

Subj.	SINGLE STROKES								%	PAIRS					%
No.	1.	2	3	4	5	6	7	Ave	Var.	a	b	c	d	Ave.	Var
1.	9	14	7	9	9	9	11	9.7	16.4	23	16	18	-	19	12.3
3.	13	14	9	5	11	6	13	10.1	34.	27	14	17	23	20.3	23.
4.	9	8	5	5	7	6	6	6.6	23	17	10	13	10	12.5	20.
5.	8	8	4	4	7	5	4	5.7	29.3	16	8	12	8	11	27.3
6	11	10	5	5	7	5	6	7	28.6	21	10	12	13	14	25.
7.	10	9	6	5	6	4	6	6.6	25.2	19	11	10	17	14.2	26.3
8.	12	10	7	6	3	4	7	7.4	27.3	22	13	10	15	14	23.3
9.	11	12	8	8	3	5	-	8.7	17.3	22	17	13	-	17.3	18.
10.	10	10	7	5	7	6	3	6.9	23.1	20	12	13	7	14	27.
11.	7	8	5	4	6	5	8	6.1	21.2	15	9	11	9	11	18.1
12.	9	5	4	7	2	5	5	5.3	29.5	14	11	7	10	10.5	19.
13.	7	8	5	4	7	4	-	5.8	26.	15	9	11	-	11.7	19.1
14	10	16	7	6	6	4	6	7.9	36	26	13	10	-	16.3	39.4
15.	7	10	7	6	7	7	7	7.1	9.2	17	13	14	-	14.7	10.7
20.	11	8	55	4	6	5	7	6.6	27.2	19	9	11	12	12.7	24.5
Tot.	144	149	92	83	102	80	89	107.5	373.3	293	175	182	124	213.2	333.
Ave.	9.6	9.9	6.1	5.5	6.8	5.3	6.8	7.2	24.9	19.5	[illegible]	12.1	[illegible]		
											11.7		12.4	14.2	22.2

It is notable that the longer strokes or groups of strokes require a longer time to make, on the average, and in the case of each subject, than the shorter strokes. The first two strokes of the "h" are made in about the same length of time, but each

requires generally over 50% more time than either of the five succeeding strokes of the word. The three upward strokes following require more time on the average, and in the majority of the cases, than the downward strokes, but are quite comparable with each other in this respect. The fourth and sixth strokes show similar length and time elements. The three last pairs of strokes, which are quite similar as to size, do not differ greatly in the time element, but are clearly differentiated from the first pair of long strokes.

No distinction can be here found between good and poor writers in the degree of rhythm. The two groups average about the same, and some of each group show comparatively good rhythm, and others comparatively poor rhythm.

The study of this exercise leads to the following hypothesis: the general tendency is for the individual to adapt the time in some relation to the length of the stroke being constructed, hence it may be expected that strokes of similar lnegth are more naturally adapted to temporal rhythm, and furthermore, rhythm, at least of this type, in ordinary writing, does not seem to be a characteristic of good writers as contrasted with poor writers. The matter is discussed more fully later on (p. 128 ff.) and provides the basis for a new interpretation of rhythm in handwriting. Other samples of writing were investigated in order to discover whether these tentative conclusions are thereby substantiated.

In complete records were gotten of the word "then," the letters "h" and "e" occuring here as in the word "he," except that here they are in context, with "n" following. It was found

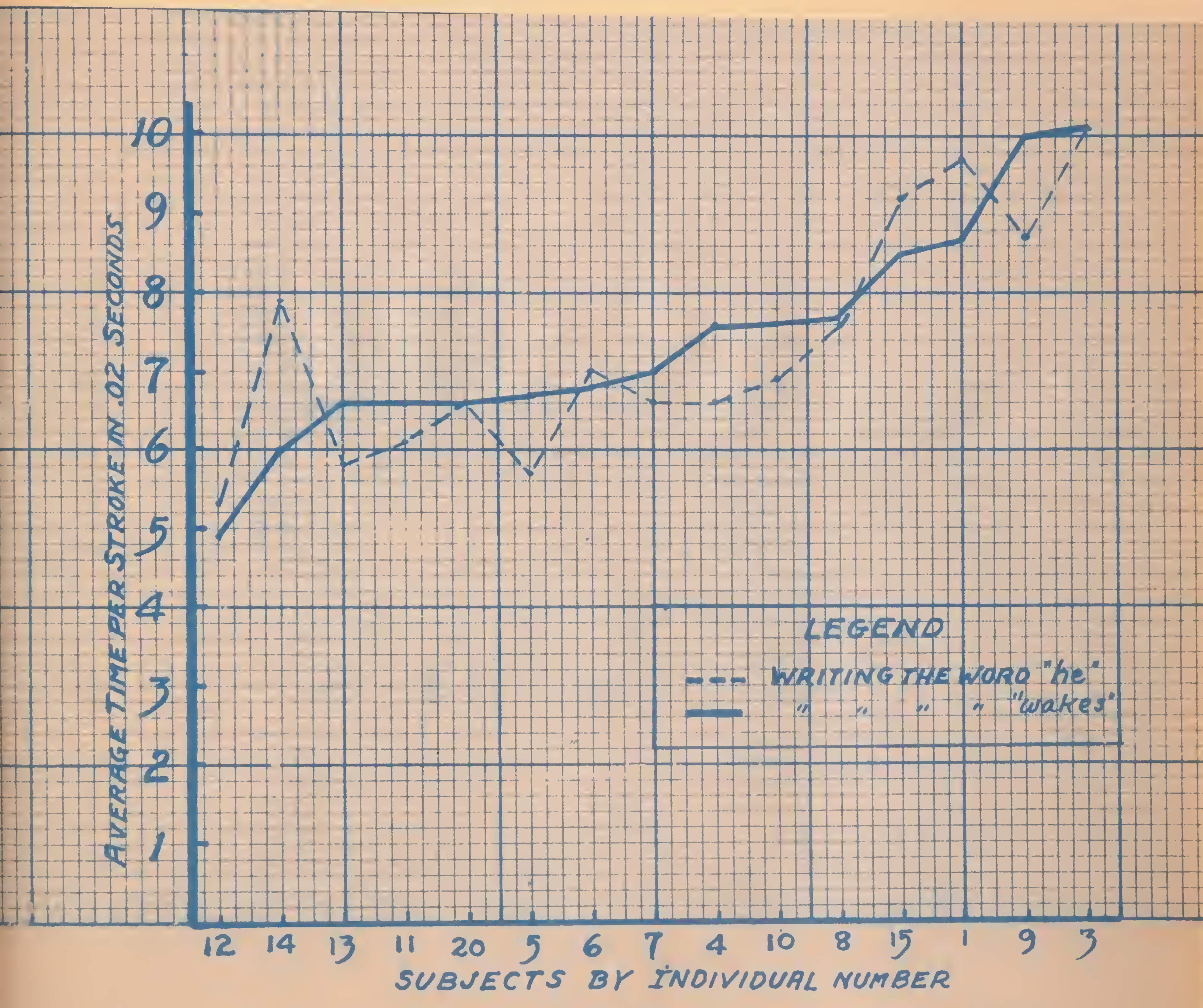
that the same differentiations between the strokes occurred as in the word "he."

The word "wakes" was chosen as a typical word involving certain complexities of letter formation in the construction of it, such as abrupt reverse curves in the "a" and "s", and special constructive difficulties as in the "k". This word, on account of these features particularly, does not yield easily to any system of rhythmic beat. The first five strokes, those of "w" are easily susceptible to metric analysis with the beat on the up or forward stroke, but fixing of the place of such a beat in the movement from "w" to "a," on the small part of the "k", and in the "s" is most difficult, as compared with the simple form met with in the word "he." The records for the same 15 subjects as those noted in Table 15 were gotten for this word "wakes." It is not necessary to present the complete data, but a summary table is here given (Table 16) which shows the average time taken by the group for each of the 19 strokes and also gives the average duration of each stroke as well as the average per cent variation.

Table 16
Average Time Spend on Successive Strokes
in the Word "Wakes" by 15 Writers
(expressed in 50ths of a second)

Stroke	1	2	3	4	5	6	7	8	9	10	11
Ave.	8	6	6.7	5.6	6.6	9.1	7.3	6.4	5.1	9.1	9.8

Stroke	12	13	14	15	16	17	18	19	Mean	% Var
Ave.	7.	8.5	4.5	7.3	5.8	7.7	9.4	10.3	7.4	25.2



DIAG 9 - SHOWING TENDENCY OF SUBJECTS TO GIVE THE SAME AVERAGE TIME TO STROKES IN DIFFERENT WORD

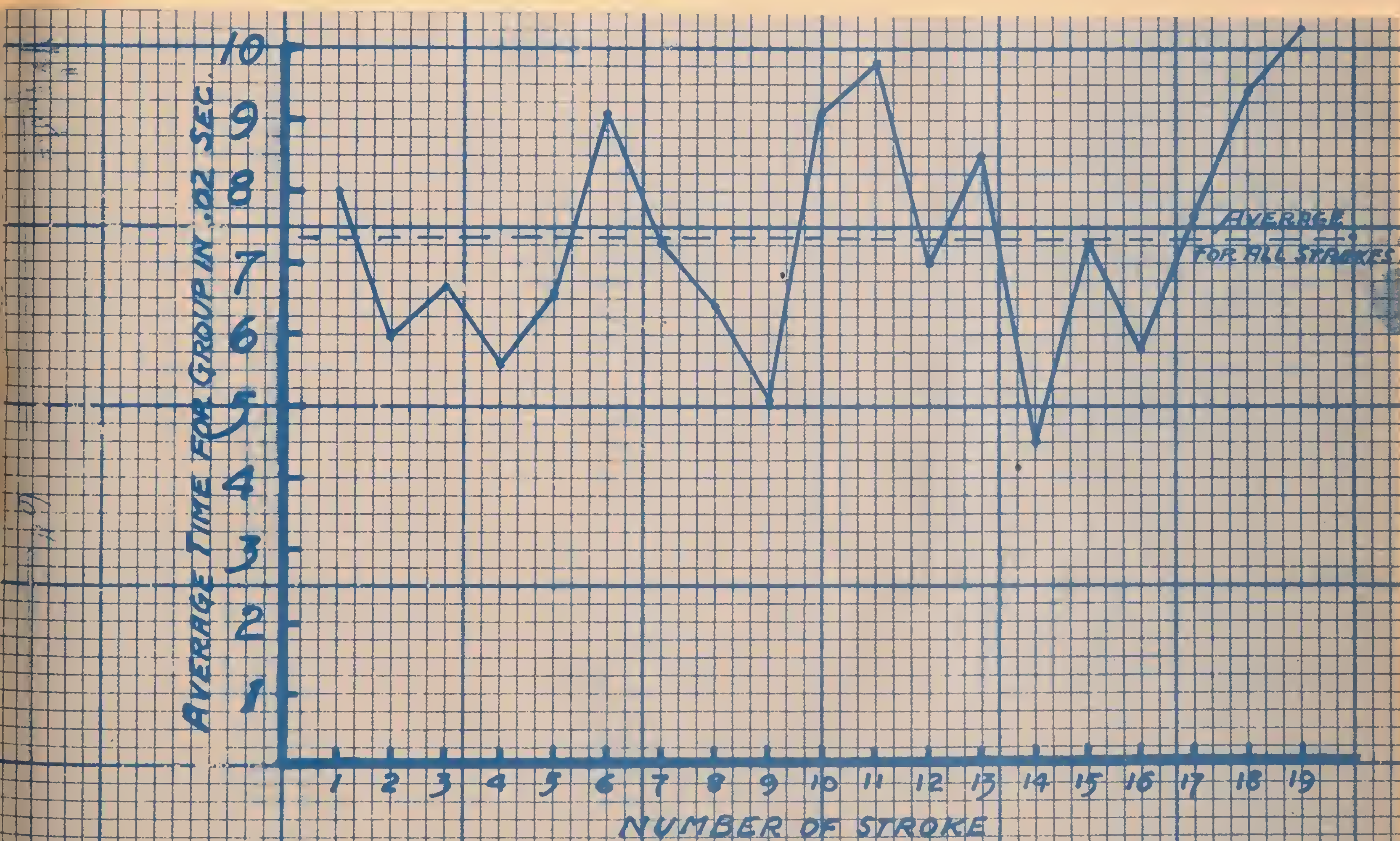
Consideration of the average duration of strokes in the two tables (15 and 16) reveals the fact that the average time periods are nearly identical, 7.2 ø and 7.4 ø respectively, and this may be tentatively regarded as the approximate average length of time spent on the stroke in ordinary writing, i.e., .144 seconds, if it be assumed that the data here presented is characteristic of the performance of groups of individuals on the average. It is at least shown to be quite characteristic of this group in these two exercises.

Another point of similarity is found in the percentage of deviation in the two cases, 24.9% and 25.2% respectively. It is possible that this figure is also characteristic. It is likely that the data from the two words "he" and "wakes" are not comparable since the distribution of long and short strokes are quite different in the two cases.

In the following tabulation (Table 17) and accompanying diagram (Diagram 9) the measures are arranged according to the rank standing of the subjects in average time spent in strokes, as shown in Table 16, and compared with their standing in results of Table 15.

Table 17.
Comparison of Subjects' Records.

Subj.#	A Time	A Rank	B Time	B Rank	Subj.#	A Time	A Rank	B Time	B Rank
12	4.9	1	5.3	1	7	7.	8	6.6	6
14	6.	2	7.9	11	4	7.6	9½	6.6	6
13	6.6	4	5.8	3	10	7.6	9½	6.9	8
11	6.6	4	6.1	4	8	7.7	11	7.4	10
20	6.6	4	6.6	6	15	8.5	12	9.2	13
5	6.7	6	5.7	2	1	8.7	13	9.7	14
6	6.8	7	7.	9	9	10.	14	8.7	12
					3	10.1	15	10.1	15



DIAG. 10 — AVERAGE TIME SPENT ON SUCCESSIVE STROKES IN THE WORD "wakes" BY 15 WRITERS

It is noteworthy that individuals show a general tendency toward giving a fixed average length of time to a group of strokes. Although a few, as Subject No. 14, show marked deviations in this average for the two words, in the majority of cases there is a close agreement, and even exact duplication in the case of subjects No. 3 and No. 20.

The tendency of the group, both on the average and by individuals is to devote unequal amounts of time to the respective strokes in the exercise. This is clearly evidenced in Diag 10 ,

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Diagram 10. Variation of Group in Average Time Spent on Successive Strokes in the Word "Wakes."

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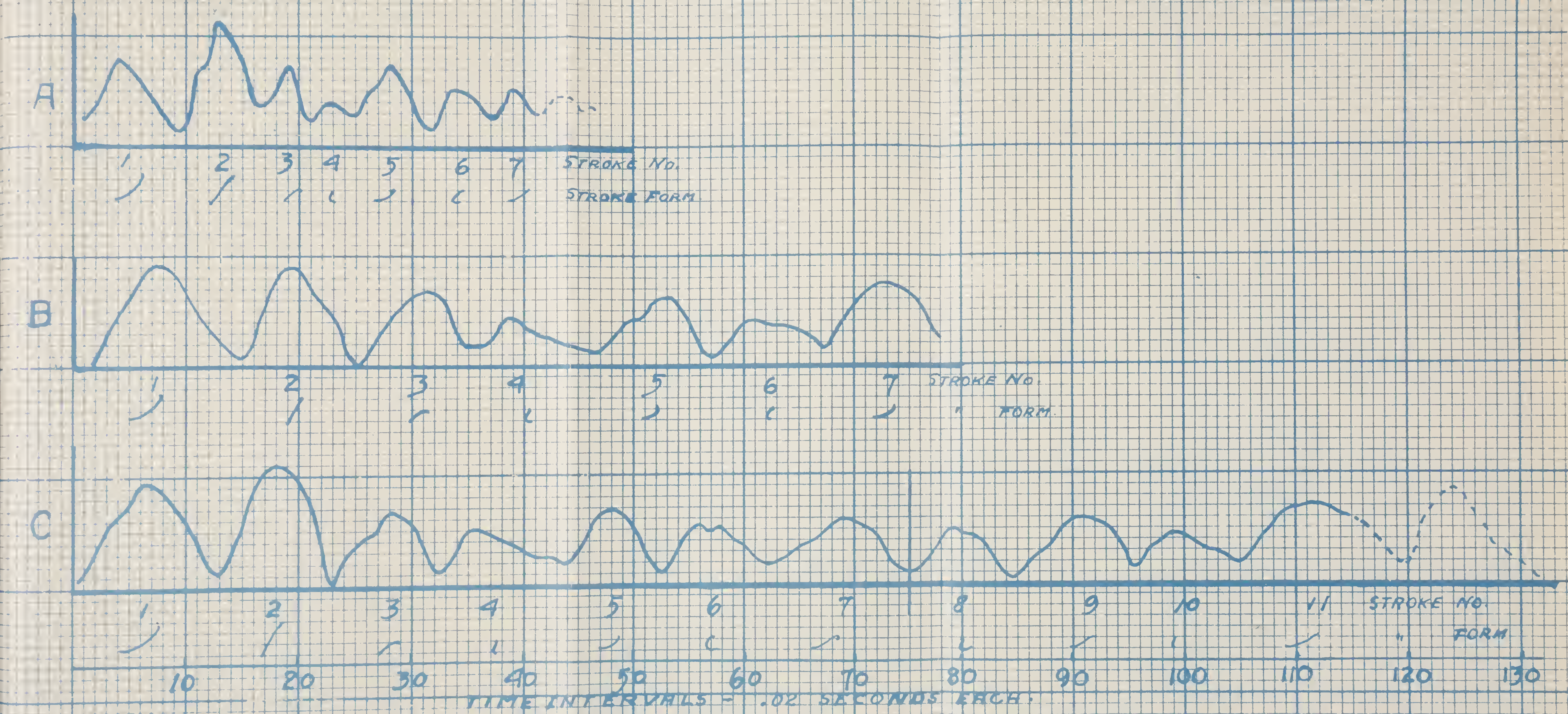
which graphically presents the average of Table 16. The range falls between 4.5 σ for stroke 14 and 10/3 σ for stroke 19. In general the longer strokes receive the greater time emphasis. The difference in duration of strokes, does not seem proportionate to the length, however. For example, stroke 6 is not generally nearly as long as stroke 10, yet it receives almost as much time. In this case and others it is found that the complexity of the stroke may be operative as a factor in the determination of the time spent.

<u>There is no marked distinction between the poorer adult writers and the better adult writers as to the degree of deviation. The children do, however, show a notably lower degree of rhythmic control, than the adults, the former having 30.1 per cent deviation while the latter have about 24 per cent.</u>

Detailed analysis of the words "Lucy," "from," and "sleep" merely substantiated the general findings noted above, and offers



DIAG. 11 – COMPARARISON OF SPEED CURVES FOR CERTAIN STROKES MADE BY SUBJECT #5 IN USUAL WRITING (A) AND IN FOLLOWING AN IMPOSED RHYTHM (B AND C)

no variant or especially new testimony, hence the tables of measures are not here presented for study and comment.

The Effect of Following an Imposed Rhythm.

This topic was quite fully treated in Part Two of this investigation in connection with simple movements, and is touched upon here only briefly as it is related to written exercises. The behavior of two adult subjects in the following of the imposed rhythm was noted. Both of these were good penmen; one (No. 5) was trained quite well in such procedure, and the other (No. 20) had had no previous drill in following a rhythmic beat while writing. The subject first wrote the exercise for record in his natural style of penmanship. The metronome was then set up and adjusted to a rate most agreeable to the subject, so that a more rapid rate produced a sense of confusion, and one slower gave a lagging sensation. The subject then practiced a few minutes until he became accustomed to conditions, and acquired freedom through drill on the exercise to be recorded, and the record was then made.

Diagram 11 exhibits a typical section (part 1) of the speed curve for normal writing as made by Subject No. 5 in comparison with two sections (parts 2 and 3) of speed curves of corresponding exercises written by the same subject while following the imposed beat. The characters "he, " "he," and "hen" are represented here in the three parts of the diagram respectively, the latter being included so as to show the same letters thrown into context.

Diagram 11. The Effect of Following a Beat.

There is a close agreement between the latter two parts, both as to distribution of speed within comparable strokes and the

organization, showing that the behavior of the subject was consistent in the following of the imposed rhythm.

The curve of speed for the first 7 strokes of parts 2 and 3 is noticeably longer than for part 1, showing a slower rate of movement. The imposed rhythm, which was as rapid as could be well followed by the subject, was much slower than his natural movement. This subject followed quite closely the rate of beat imposed, the average time spent by him on each pair of strokes being about 21.6 ∅ while the rhythmic beat was at the rate of 22 ∅, or 135 per minute. The writer made the up stroke on the incidence of the beat.

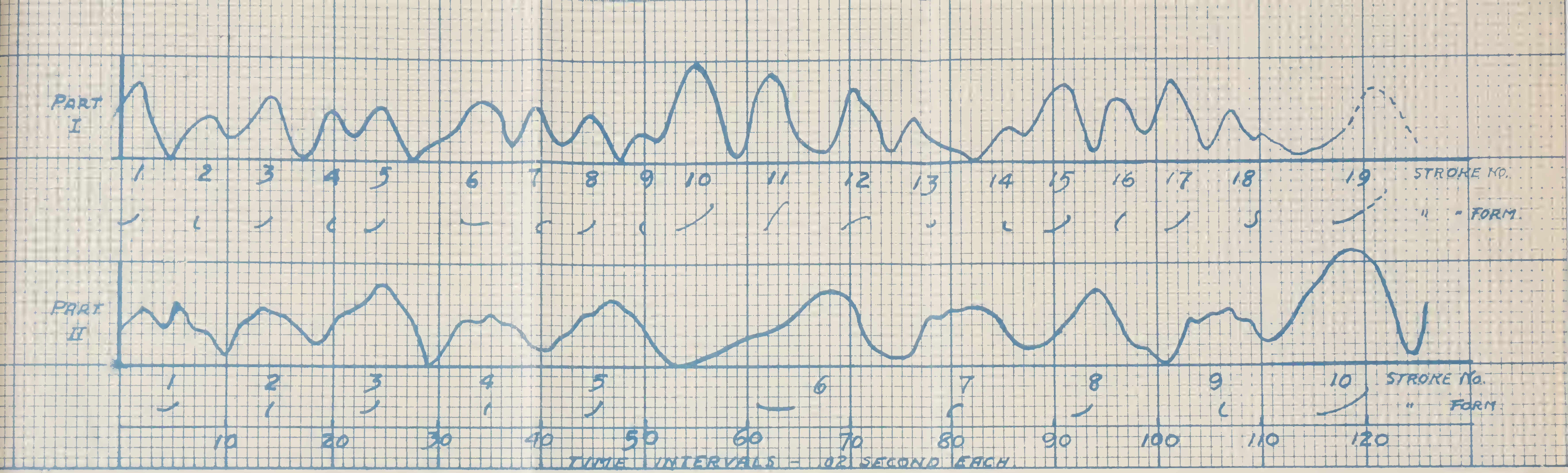
The time organization is much different when the rhythmic beat is followed than when the writing is spontaneous, as shown by the following tabulation (Table 18) in time measures of the

Table 18.
Comparison of Time Distribution Without and With Imposed Rhythm.

Stroke No.	1	2	3	4	5	6	7	Tot	Ave	Dev. Tot.	Dev. %
Spontaneous	9	7.5	4.5	4.	7.	5.	4.	41	5.9	11.9	29.
Imposed	14	10.	10.5	11.	10.5	10.	11.	77	11.	6.	7.8
Imposed	12	10.	9.5	11.5	9.	9.5	12.5	74	10.6	8.6	11.6

length of a 50th of a second. The time for each stroke is increased on the average about 80%. The time distribution in the following of the imposed rhythm if more rhythmical in the sense that successive strokes are given more nearly equal amounts of time; the deviation in the duration of strokes made in spontaneous writing being about three times that of the exercise with imposed rhythm.

The exercise constructed following the beat was appreciably larger than in spontaneous writing, and the adaptation to the larger



DIAG. 12 - COMPARISON OF SPEED CURVES OF SUBJECT #5 IN WRITING THE WORD "wakes" NATURALLY [PART I] AND FOLLOWING AN IMPOSED RHYTHM. [PART II] ONLY FIRST 10 STROKES NOTED IN PART II.

size, whether cause or result, is accompanied by the increase of time rather than the increase of speed except in the smaller strokes.

There is no great contrast in the organization of speed relations within the stroke in this exercise as due to the effect of the rhythmic beat. The subject comes to a point of rest at the end of the second stroke on the "h" in the following of the rhythm, but does not do so in his normal writing. There is some suggestion of minor irregularities in speed progression, especially in strokes 4, 6 and 7 of Part 3 which are not evident in Part 1.

This characteristic is much more evident in the speed curve for the word "wakes" (Diagram 12) as written on the same occasion, and under the same conditions of imposed rhythm, which is given (Part 2) in comparison with the curve for normal writing (Part 1).

Diagram 12. Comparison of Speed Curves of Subject No. 5 for the Word "Wakes" as Written Without and With Imposed Rhythm

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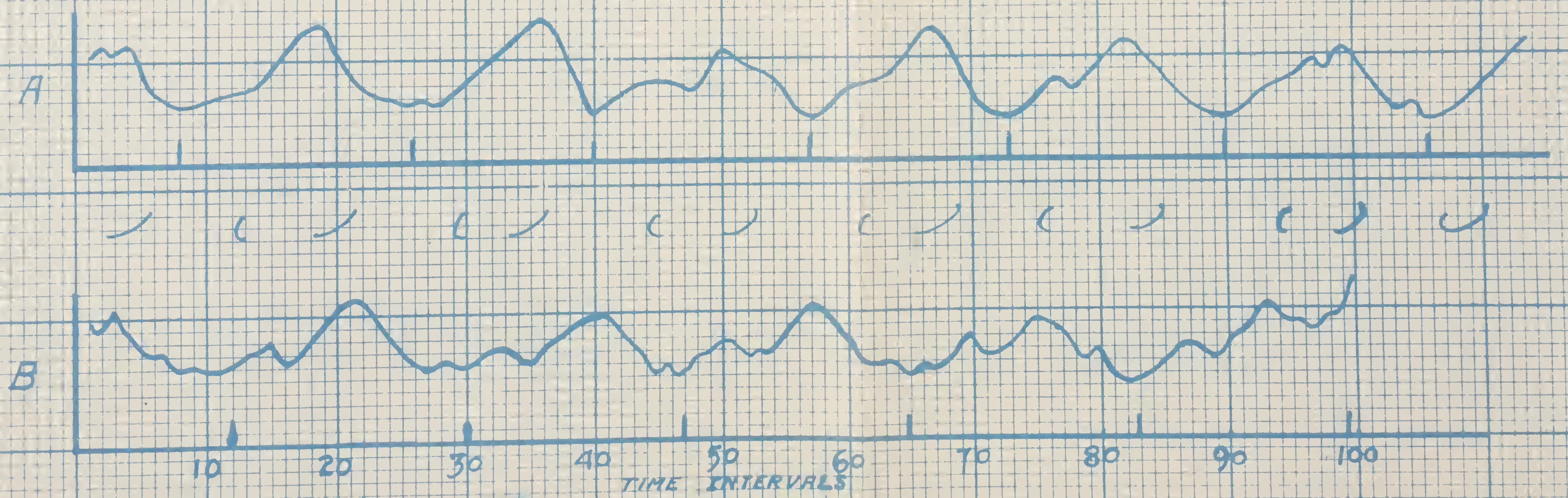
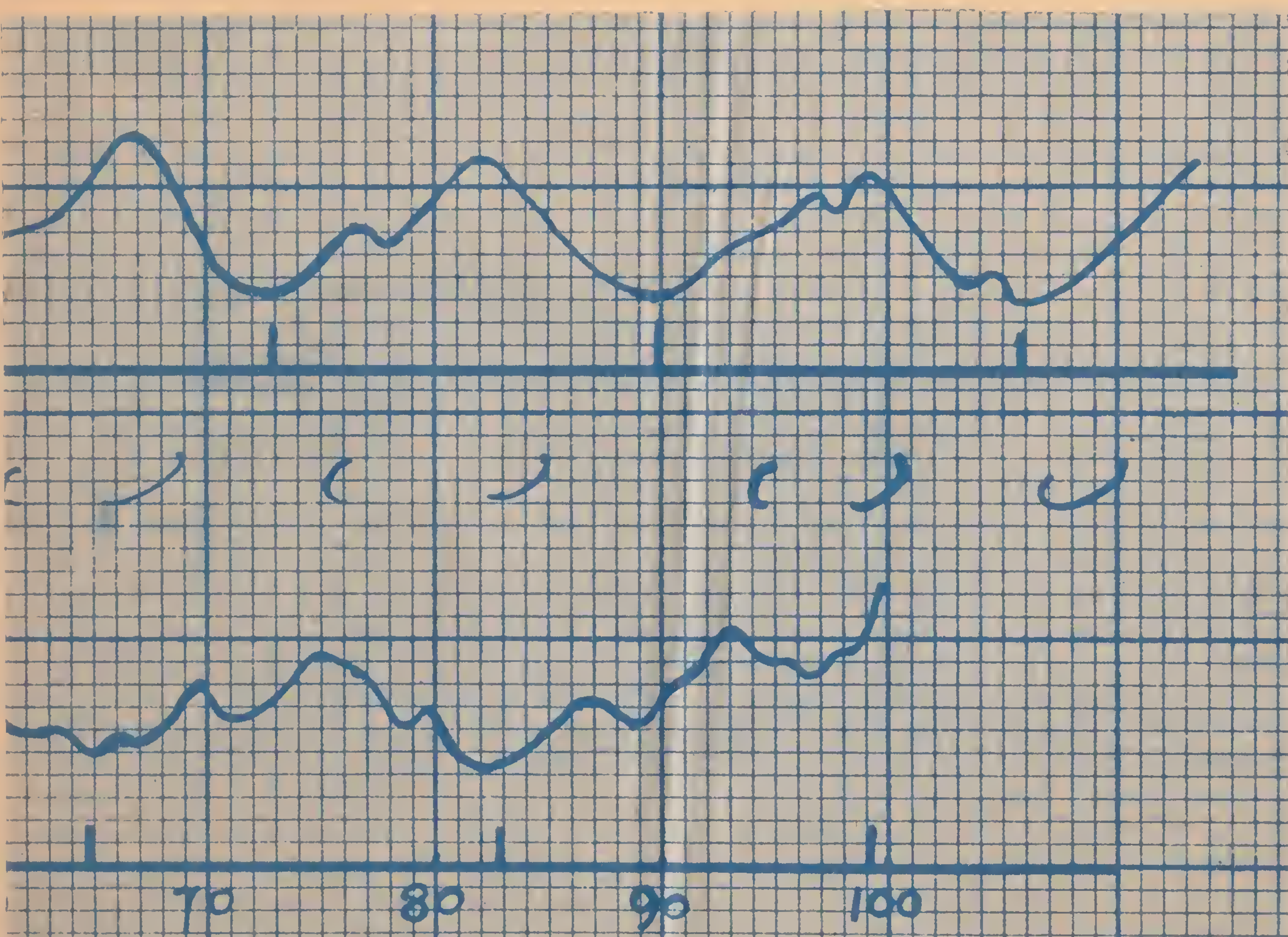
Many curves in Part 2 show a hesitating, wavering progress, as though the writer were uncertain of his control, and indeed similar in this respect to the speed curves of those subjects who evidence poor coordination, as before noted (p. 104), but in marked contrast to the steadiness as shown in Part 1.

It can hardly be expected that one's rate of movement could be slowed down greatly from the natural or accustomed speed, and not have an appreciable effect on the formation of the writing. Though the written forms of this subject do not show any great degree of incoordination when following the imposed rhythm there are present slight irregularities in curves which do not characterize his ordinary penmanship. The greater the degree of adjustment in



DIAG. 13 - COMPARISON OF SPEED CURVES OF RUNNING OVALS AS MADE BY SUBJECT #20 WITHOUT IMPOSED RHYTHM (A) AND WITH IMPOSED RHYTHM (B)



: OVALS AS MADE BY SUBJECT #20 WITHOUT
ED RHYTHM (B)

time, the more hesitating the movement seems to be, as evidenced by Diagram 12. Stroke 4 is increased from 4.5 σ to 11 σ, stroke 5 from 6 σ to 13.5 σ, stroke 7 from 5 σ to 14 σ, and stroke 9 from 4 σ to 10 σ, and in each case these strokes do not evidence the definite organization characteristic of strokes 10, 11 and 12 for example, which are given a much smaller proportionate increase from the spontaneous form.

The effect of the imposition of rhythm on Subject No. 20 is shown in a typical case in the speed curves of Diagram 13. The

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Diagram 13. Comparison of Speed Curves for Direct Oval by Subject No. 20 without and with Imposed Rhythm.

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first represents the direct oval made spontaneously, and in general shows a steady progress, with little evidence of hesitation, or vaccilation of speed. The second, which was made while following an imposed rhythm of about 120 beats per minute, shows a wavering of the speed rate throughout which is significant of an intruding factor. The movement in this exercise, while more rapid than the beat which was to be followed in the ratio of about 18 σ to 21σ is yet somewhat slower than the ordinary writing. The writer did not succeed in following the beat closely, in fact constantly tended to approach his own habitual rate of movement, but he tried to do so, and the conscious attempt, while not fully successful in adapting the rate, probably greatly affected the organization.

There is evidently a danger that in the attempt to follow a rhythmic beat, especially when it is slower than the normal rate, one may be held back in his movement with a disastrous result to the form of the product. What would be the effect on an adult of

an attempt to follow a rhythm faster than his normal rate is problematical, since such a rhythm could not be consciously followed, except possibly in rare cases. Experimental investigation of the writing of children under these conditions would be valuable. We have already noted (pp 47,53.) that the children are affected differently than adults by the imposition of rhythm, especially in regard to arm-finger relations, and it is probable that this unhabituated group might be greatly benefited in rapidity and coordination of movement by the imposed beat.

Speed of Movement.

Thus far we have been concerned with the duration of strokes; now we will turn to a consideration of the rate of movement within the stroke. The marked changes in speed of the penpoint during any exercise by individuals have been noted, especially with reference to the speed curves of Plate II. It is noteworthy that, where the individual's organization permits, there is a definite point of maximum speed in each stroke, as well as points of minimum speed just preceding and following the stroke. The minimum and the maximum rates of speed of successive strokes , in the writing of any exercise, are found to vary greatly among different individuals, and also not to remain constant in the case of any one individual, in various corresponding units of the exercise. This is shown in the following tabulation (Table 19) giving successive maximum rates only.

The maximum speed is in most cases discovered to fall reg -

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ularly in the upward stroke of the slanted oval, while the minimum speed is usually found at the lower curve of the oval,

Table 19.
Maximum Speeds Attained within Successive Up-Strokes in Writing the Direct Running Oval.

Subj.	STROKE NO.													%
No.	1	2	3	4	5	6	7	8	9	10	11	12	Mean	Var.
1.	19	20	19	19	21	23	20						20.14	5.3
2.	13	12	11	12	15	15	13	14	14	16	12		13.5	9.1
3.	12	13	16	14	16	15	14						14.3	8.3
4.	13	13	13	13½	12½	12	14						13.	3.3
5.	8	8	7	8	8								7.8	4.1
7.	8½	10½	12½	11	12½								10.6	12.8
8.	12½	12	12½	12½	12	13	13½	13					12.6	3.2
9.	12	9	10½	9	10	9½							10.	8.3
10.	8	6	6	6½	7	7	6	5½					6.5	9.6
11.	9½	8	8	11½	10½	10½	11	10½	10	10½	9½	10½	9.9	8.7
12.	10	10	9	9	12	9	11	13	10½	11	11½		10.5	10.
13.	9½	7½	7½	8	8	9	8	7	7				8.	5.6
14.	7½	6½	8	7½	7	6½	6½						7.1	9.
15.	15	14	14	12	12½	11½	11	11					12.8	11.4
16.	10½	8½	9½	9	10	9½	10						9.4	5.7
17.	13	17	17½	18	13								15.7	13.8
19.	10	11½	9	10	8½	7½							9.2	11.7
20	9	9	9	8½	8	9	10	10	10½				9.2	4.7
												Total	200.3	136.3
												Mean	11.1	8.03

just preceding the upward stroke. The next to the highest speed is attained in the middle of the down stroke, and the next to the lowest speed in the course of the curve at the summit of the oval just preceding the downward stroke, these relations varying, however, with the elements of the oval.

Suggestion has already been made that the duration of a stroke varied to some extent with the length and complexity of the stroke. (pp. 116,117,120.) The relationship between the duration, rate of movement, and the length of stroke was analyzed to some extent, and the results with a typical case are here summarized in Table 20, the construction of a direct oval by Subject #1 being under consideration.

It is noteworthy that the up-strokes are on the average longer than the down strokes and also require more time, as well

Table 20

Comparison of Duration,Length,and Maximum Speed in Repetitive Exercise

DOWN STROKES				UPSTROKES			
Stroke	Duration	Length	Max.Sp.	Stroke	Duration	Length	Max.Sp.
2.	7	243	42	3	8	318	53
4	7	263	46	5	7	266	50
6	7	250	43	7	8	312	58
8	6	263	48	9	8¼	318	53
10	6	225	44	11	7½	284	49
12	6½	214	41	13	8¼	268	44
14.	6	201	37	15	7	300	54
16	6	231	45	17	7½	294	51
18	7	231	41	19	7½	300	50
20	6½	206	39				
Mean	6.1	233	42.6		7.9	296	51.4
Mn.Dev.			2.6				2.8
Ratio of Means	1	38.2	7		1	37.5	6.5

as a greater maximum speed. The variation in maximum speed is about the same in both groups. When one considers the relations between the various measures by ratio it is found they are about the same in the up-strokes as in the down-strokes, with a suggestion of a slightly lower proportionate maximum rate, and a slightly higher proportion of time being spent on the longer or up strokes. There is,however, <u>no absolute relationship of</u> this kind holding in respect to individual strokes, as we find a stroke of 231 m̸ being made in the same time as one of 300 m̸, and one of 268 m̸ showing a smaller maximum rate than one of 263 m̸. The evidence here given points to the conclusion that the length of the stroke alone is not the determinant of either the maximum speed or duration of stroke, but that it is one factor in a complex with other significant elements.

The writing of a child offers remarkable contrasts in the relations of length, maximum speed and duration of strokes, to that of the adult; in fact the indirect curve as made by Subject Number 18 reveals no correlation between these elements, and this record is quite typical of the performance of younger children. The stroke is not usually made

with a free movement as a unit, as has been before noted, and the child writer has not yet adjusted himself to any definite relationship between the elements of speed and duration within the stroke.

But when no consideration is given to the child writing with its particular type of incoordination there yet remains to be found the explanation of the lack of relationship between the length of particular strokes and the speed with which they are made. This is doubtless found in the complexity of the stroke with special reference to the changes in curvature.

It is inadequate to compare two curved strokes as to length unless they are both of the same shape. The curved stroke, used in writing is constantly changing direction, so that possibly only very small sections can be regarded as perfect arcs. But any curved line of writing, in which there are changes in the degree of curvature, and this class probably constitutes the majority, may be considered as divided into sections of curved arcs, each with its own radial measure, and a more or less gradual transition from one to the other. The limits of such arcs may be difficult to define, but if the changes are quite sudden and angular the distinction between successive sections is more clear.

The total line of writing should perhaps be regarded, not so much as separated into successive strokes as into arced portions of greater or less perfection of form. From this point of view, a stroke, as commonly designated, is more properly a section of the written line made up of an arc, or a complex of arcs, tending to progress in a definite direction and having its limits in a more or less abrupt turn, or a definite point of stoppage, in which case the penpoint comes to a rest, at least for a small period of time.

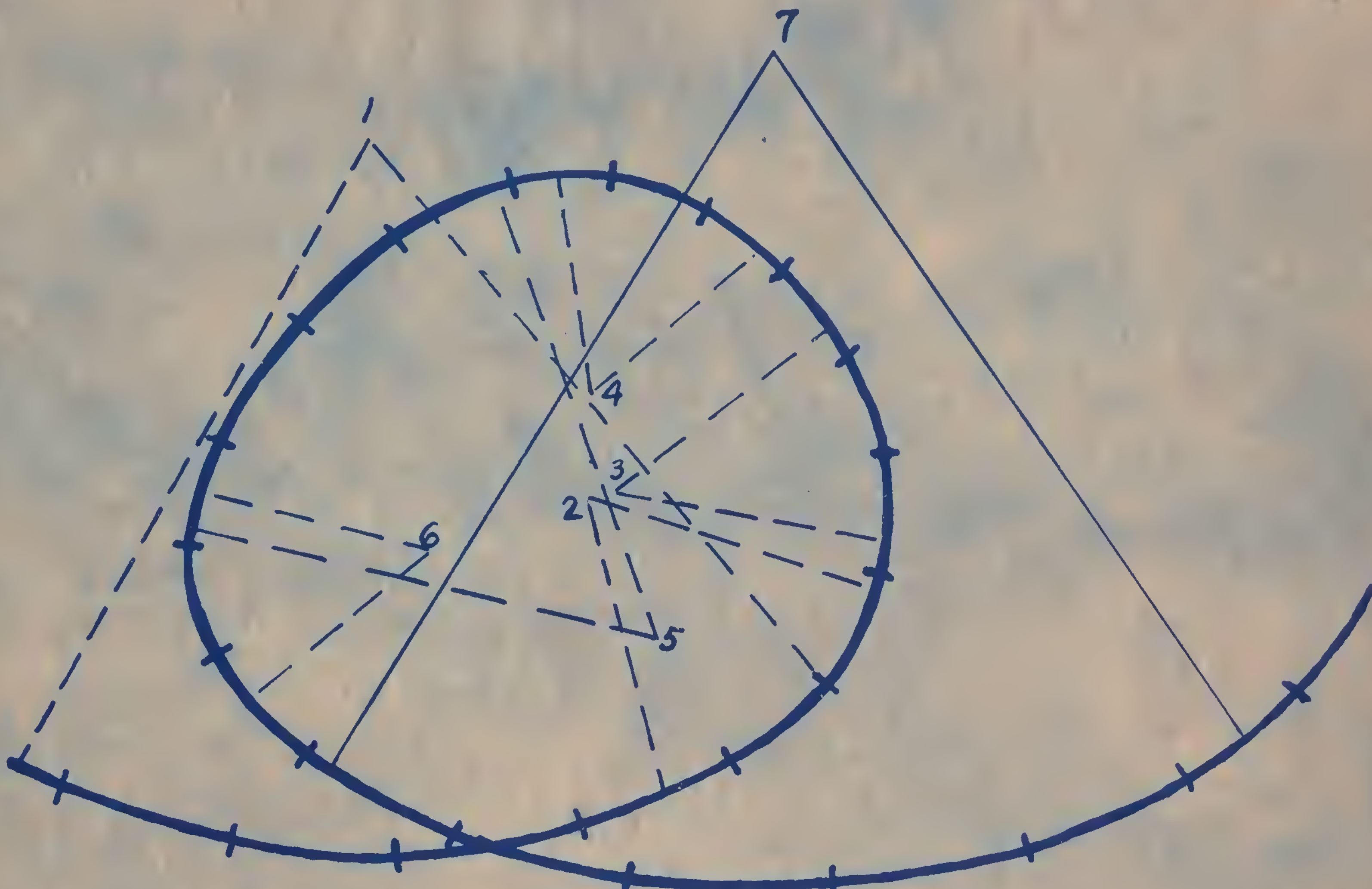

FIG. 18— PORTION OF TRACING OF DIRECT CURVE ANALYZED INTO SEPARATE ARCED SEGMENTS.

Microscopic analysis of the writing indicates that reversals of of direction following a full stop are rare, and that changes of direction such as occur at the end of the first stroke on a "t" or "u" are accomplished by means of a small loop which is indeed invisible to the eye in many cases of ordinary writing, and may be so minute as to escape detection in even such an analysis as was here made.

Freeman notes (1) the general principle as stated by Binet and Courtier and Jack that the speed is proportional to the radius of the curve and suggests that it would hold roughly if the speed were due to mechanical factors alone.

The oval as written by Subject No. 20 was first used as material for study along the lines here suggested, to see what was the influence of curvature on the speed attained within the stroke. In Figure 18 is shown a portion of this oval broken up for measurement into 7 arced portions, having their centers of radiation in order, as indicated by the numerals 1 to 7 respectively. It is notable that the radial lengths differ greatly. The lengths of these radii were measured in mm. and made comparable with the maximum rates of speed per 50th of a second. The measurements of 33 arcs, selected at random where the differentiation was clear, were made and tabulated. Casual inspection of the table revealed a definite

Figure 18. Portion of tracing of Direct Curve. Analyzed into Separate Arced Segments.

(1) Freeman, F.N. An Experimental Study of Handwriting. Psych. Monthly, #75, p. 26.

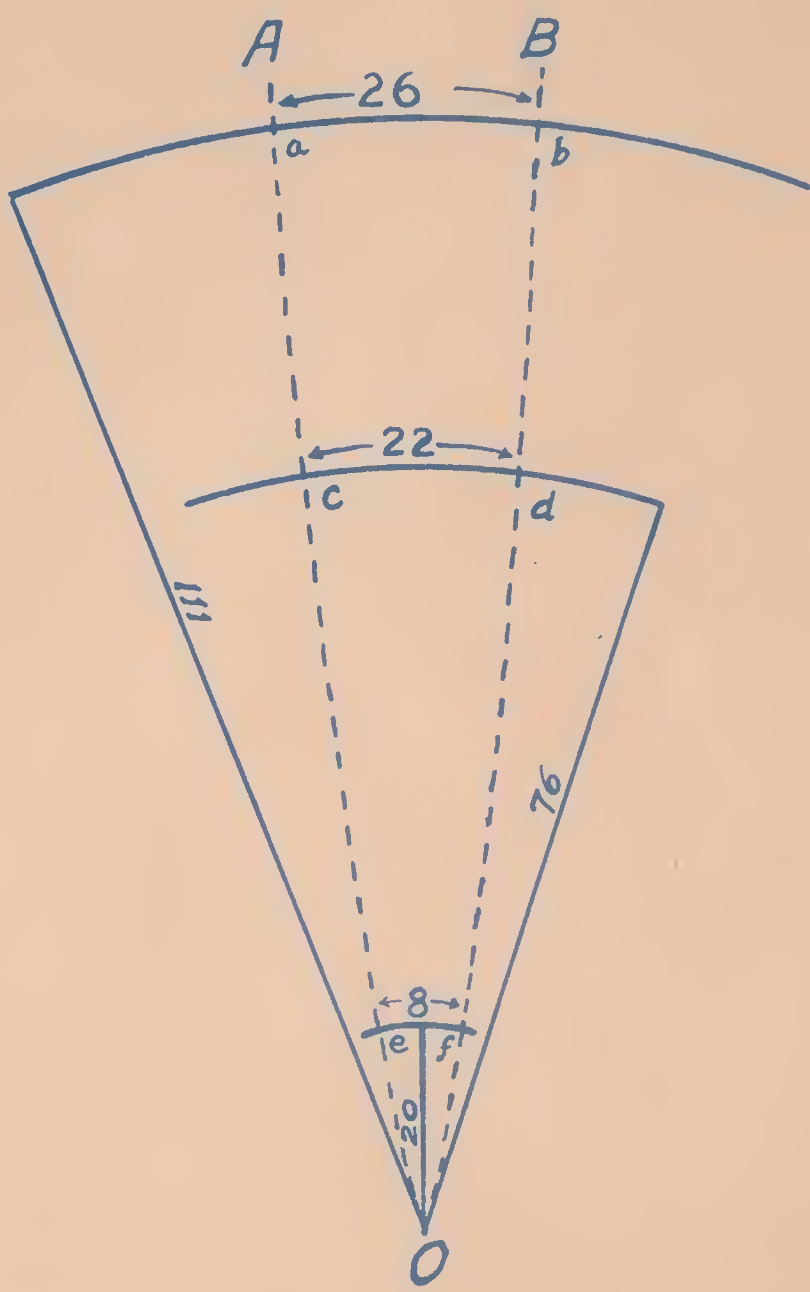

FIG. 19 – RELATION BETWEEN RADIAL LENGTH OF ARC AND MAXIMUM SPEED WITHIN THE ARC. SUBJECT #20.

direct relation between the length of the radius of an arc and the maximum speed attained within the respective arc. The lowest radial length of 20 μ is associated with the lowest maximum rate of 8 μ, while the longest arc radius, one of 111 μ swings an arc having a maximum speed of 26 μ, which is the highest recorded for this exercise. The coefficient of correlation between the radial length and the maximum speed, as computed by the Spearman Rank Method, is .96.

The table need not be reproduced here but is presented graphically in Diag. 14 in order to show the correlation between the two elements under consideration. This diagram is placed with others in a plate (Plate Four) for comparative purposes. The evidence is indisputable that the correlation exists to a strong degree and in a positive direction. The line of regression here outlined suggests, however, a curved rather than a straight line relationship with a possible falling off in regular increase of speed after the radial length of 30 μ has been reached, and a tendency for the rate to reach a fixed limit as the arc approaches a straight line form.

In Figure 19 this relationship is shown in diagrammatic form. The three arcs, having radii of 20 μ, 76 μ and 111 μ respectively

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Figure 19. Relation between Radial Length of Arc and Maximum Speed within the Arc. Subject No. 20

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from the common center O, have measured off upon them the segments e-f, c-d, and a-b measuring 8 μ, 22 μ and 26 μ respectively. Through the limits of these segments representing maximum speed rates, the lines AO and BO are drawn to indicate by the distance between them the hypothetical speed rate for all intermediate, as well as external points. The testing of this diagram at any radial length showed

approximately exact agreement with the facts of measurement as tabulated for this writer. In fact, with the diagram in hand one might fortell with comparative exactness the rate of maximum speed at any point, in case the radial length of the involved arc could be discovered, and *vice versa*. This figure shows quite clearly the lessening of the proportionate rate of speed as the radial length increases beyond a certain point. This would indicate that large writing could not be done as rapidly in proportion as small writing, since the arcs would necessarily be of greater radial length. For this writer, at least, the largest arc denoted seems to show a speed relatively about one-half as great as with the small, though the absolute rate of movement is greatly increased.

The oval above noted was one made in the attempt to follow imposed rhythm. In the same way an indirect running oval, made spontaneously by the same writer, was analyzed with similar results. The same, apparently stable, ratio between the speed and radial length occurred in this case, with very high correlation and, when graphed, a line of regression practically identical with that in Diagram 14. Considering that these ovals were written under different circumstances and are different as to form, the first being direct and the latter indirect, it is evident that the writer shows remarkable habituation of relationship between the two elements under consideration.

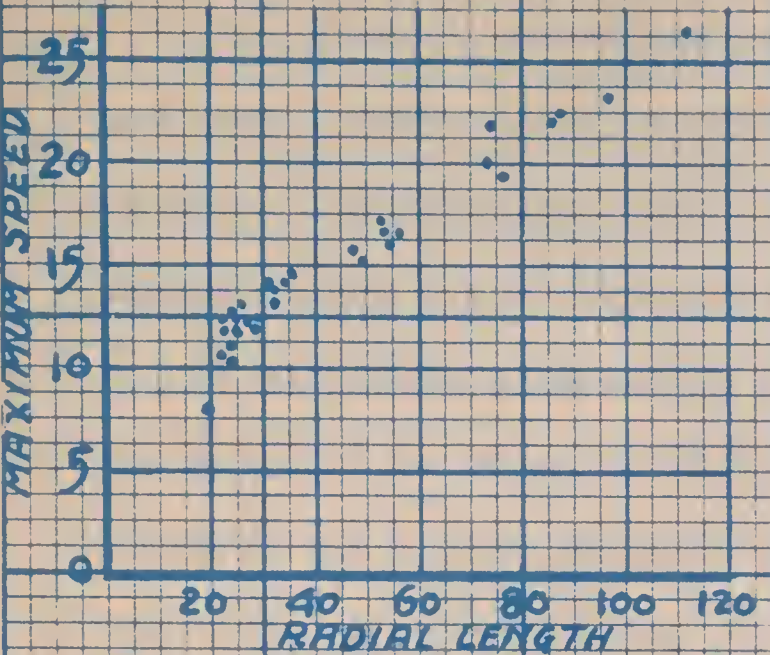
The writing movement of this subject is characterized by remarkable fluency, freedom and smoothness, his whole behavior giving an observer an impression of machine-like regularity. It will be well to analyze the records of others, with a view to noting the influence of this characteristic. Other subjects who resemble No. 20 in type of movement will first be considered.

The behavior of Subject No. 1, though quite smooth and regular, with evidence of free movement, differs from that of Subject 20 in the greater emphasis on finger movement. He is, however, quite consistent in this respect, and shows a tendency throughout all his writing to let the finger movement cooperate with the arm movement.

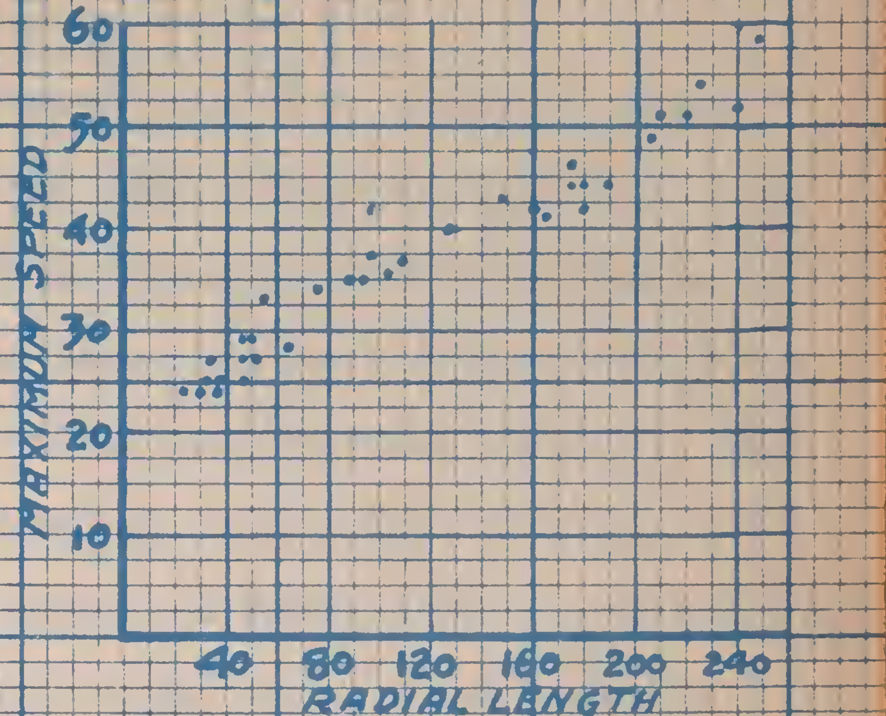
The direct running oval was analyzed as to the relation between the radial length and maximum speed with results as shown graphically in Diagram 15. It should be noted that this oval is much larger than that made by No. 20 and the measures for both the radii and maximum speed are larger, necessitating a reduction of the scale to one half that of Diagram 14. The high degree of positive correlation is evident. The 38 arcs measured were quite close together, giving a very thorough distribution throughout the line of movement. The results are very suggestive of a straight line relationship in the case of this subject, with a slight leveling in the arcs of medium size.

Subject 2 is an adult who may be classed as generally poor writer. His position and movement are all that can be desired in point of holding the pen, and fluency of motion. He has never had any systematic training in penmanship, and has made no voluntary effort to attain the correct forms, position or movement, though he makes use of very little finger movement. The analysis of the indirect oval, as made by this subject, shows a clear relationship between the radial length of the curves and the maximum speed attained, as depicted in Diagram 16. The line of regression is in this case a consistent curve, signifying a lessening of the increment of speed with increased size of the arc. This writer is classed as a poor writer, but his chief difficulty seems to lie in the proper formal organization of the various parts of forms, rather than in motor control, since he has such smooth, fluent movement.

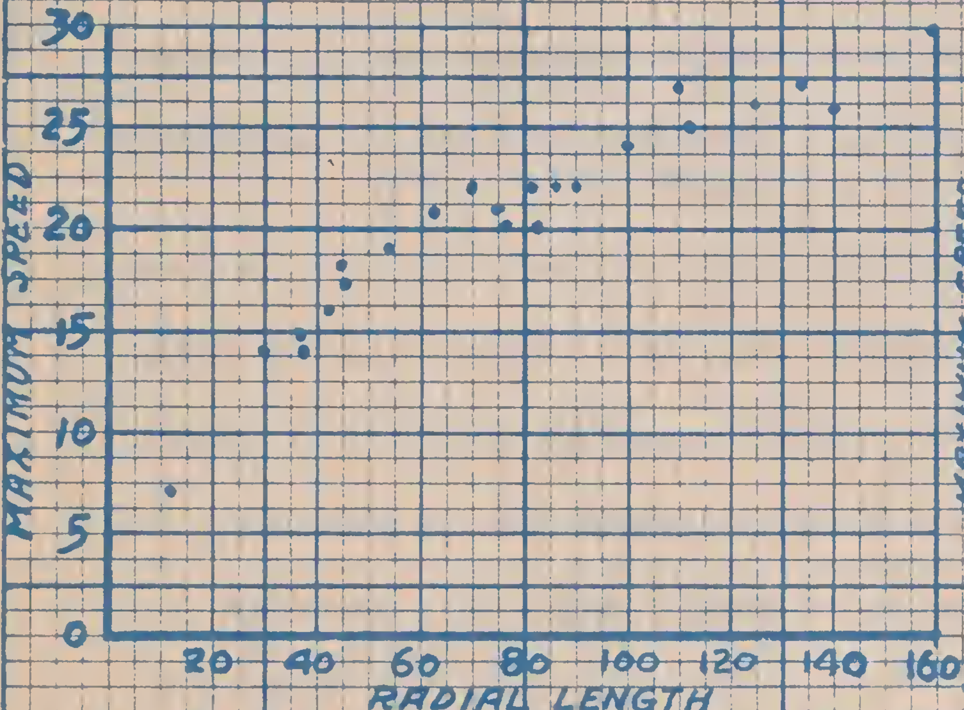
PLATE IV



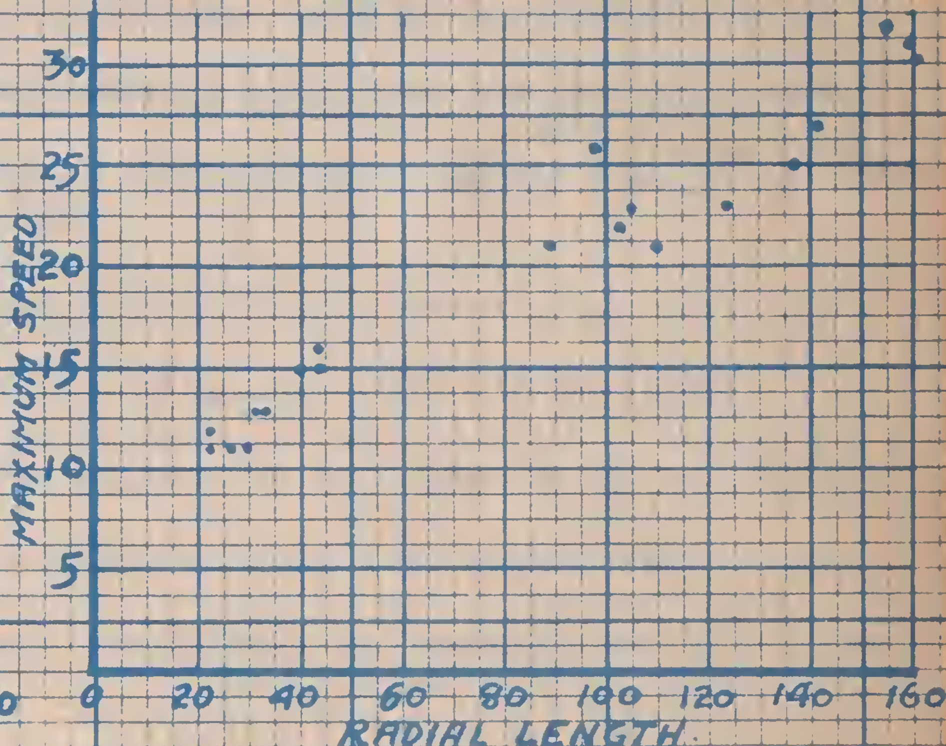
DIAG. 14 – SUBJECT No. 20



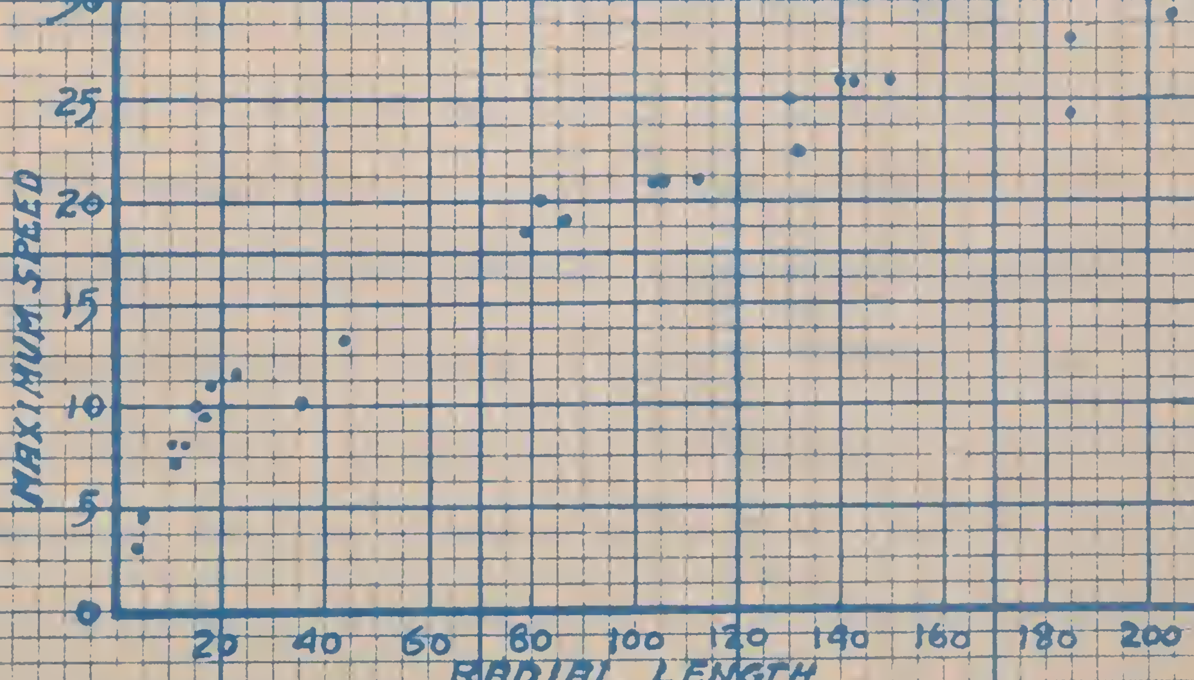
DIAG. 15 – SUBJECT No. 1



DIAG. 16 – SUBJECT No. 2



DIAG. 17 – SUBJECT No. 3



DIAG. 18 – SUBJECT No. 4

SCATTER DIAGRAMS SHOWING RELATION BETWEEN CURVATURE OF THE ARC AND MAXIMUM RATE OF MOVEMENT WITHIN THE ARC

– SUBJECTS HAVING GOOD MOTOR COORDINATION – WRITING INDIRECT OVALS. –

Subject 3, an expert penman, recently in the employ of one of the great penmanship systems, has a movement which is very free and almost flourishing, using the arm movement almost exclusively on the large strokes but depending on finger movement to a great extent in small strokes, although reported to be an arm movement writer. His penmanship is of very high grade according to standard forms. His record, as portrayed in Diagram 17, shows notable correlation between the size of the arc and the speed with which it is constructed. A straight line regression is here suggested. The one measure which

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Plate 4. Relation between the Radial Length of a Curve and the Speed with which it is made.

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seems to lie outside of and above the line of regression occurred during the shift between words, and might be the result of shifting the fulcrum of leverage, perhaps in the use of the whole arm from the shoulder in adjustment to a new position, as indeed was the general habit of the writer.

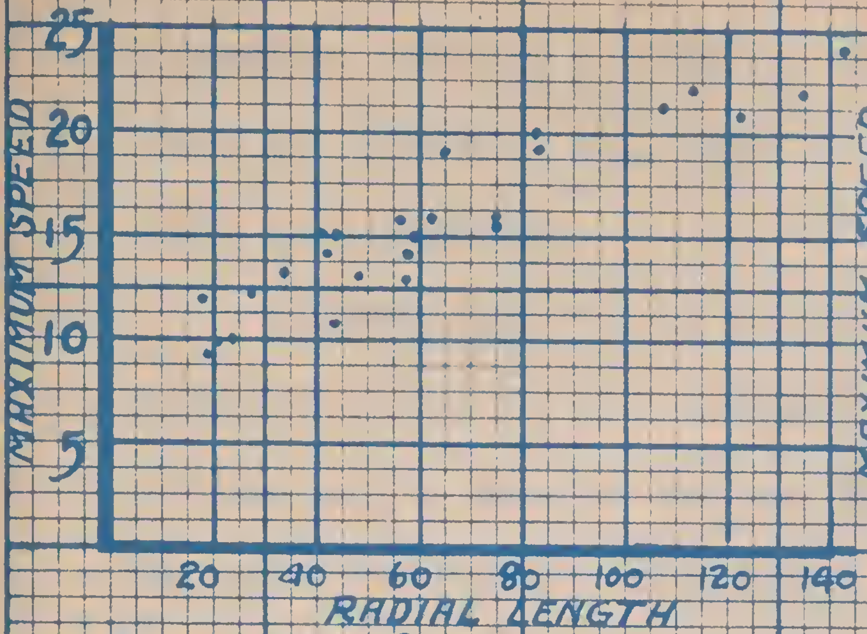
Subject 4 is considered a poor writer as far as formal penmanship is concerned, especially in his rapid style, yet there is a confidence and certainty as well as a fluency in his movement which indicates fair motor control. The speed curve of Plate II shows remarkable uniformity of organization in successive similar strokes, with good appreciation of rhythm. He medes use of thumb finger and wrist almost exclusively. He has had no systematic training, but has improved his own writing greatly through deliberate attention to regulation of movement. The Table of Correlation Diagram 18 indicates the direct relationship of the radial length to maximum speed with possibly less deviation from the line of regression than was the case

with the previous subject. There is flattening of the line of regression in the upper measures and a suggestion, consequently, of lower correlation. The very compact distribution in the lower measures is noteworthy.

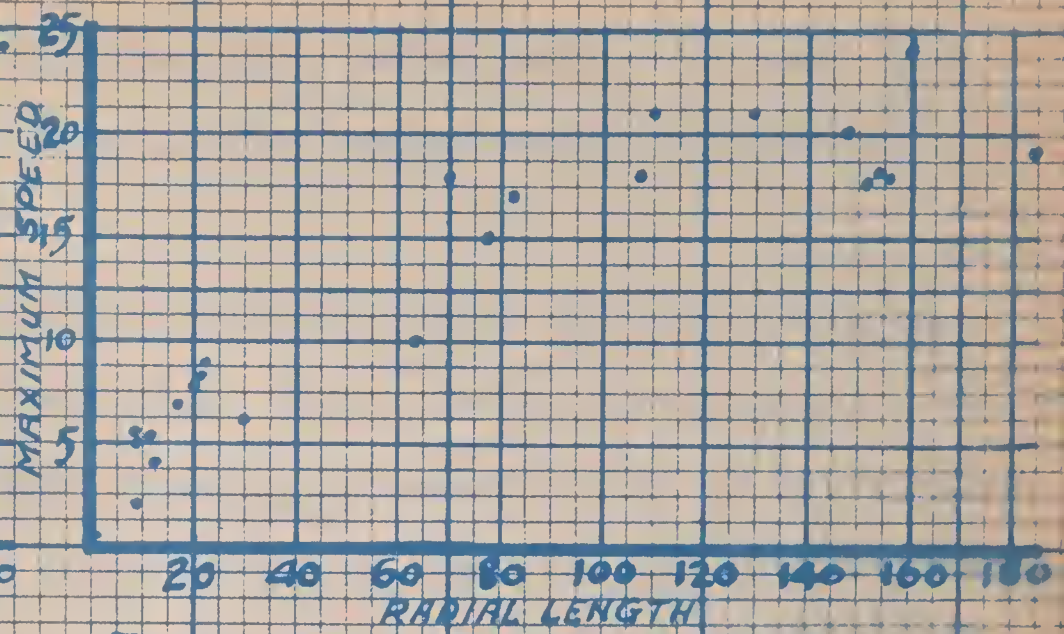
Analysis was made of the records of a few subjects who evidence a lack of motor coordination in the written product (cf. Plate II). Subject #11 is an adult writer who uses finger movement almost exclusively, exhibiting almost no use of the forearm or flexion of the wrist. The finger movement is cramped and stiff, though the subject is quite a rapid writer, with an average rate of about 142 letters per minute. Though the line of writing for this subject is not wavering, there are more or less abrupt changes of direction which are destructive of form. The data showing the degree of correlation is presented graphically in Diagram 19. This subject also shows a positive correlation between the two categories, but the loci of the measures are not so closely grouped in a definite indication of a line of regression, thus showing a less exact relationship than was the case with those subjects before studied. The trend of the measures also lies flatter with the base line than was the case with them, indicating a slower speed relative to the size of the arc.

Subject 9 is a poor adult writer who has a clumsy use of arm movement to some extent, and who finds it very difficult to control adequately any of the arm and finger muscles used in writing. His writing shows, not mere abrupt changes, but also minor waverings in direction. Diagram 20 shows a similar record to that of Subject 11 above noted. There is the same tendency to direct correlation and the same scattering of loci so as to make the line of regression less definable. There is also the leveling of the curve in the upper

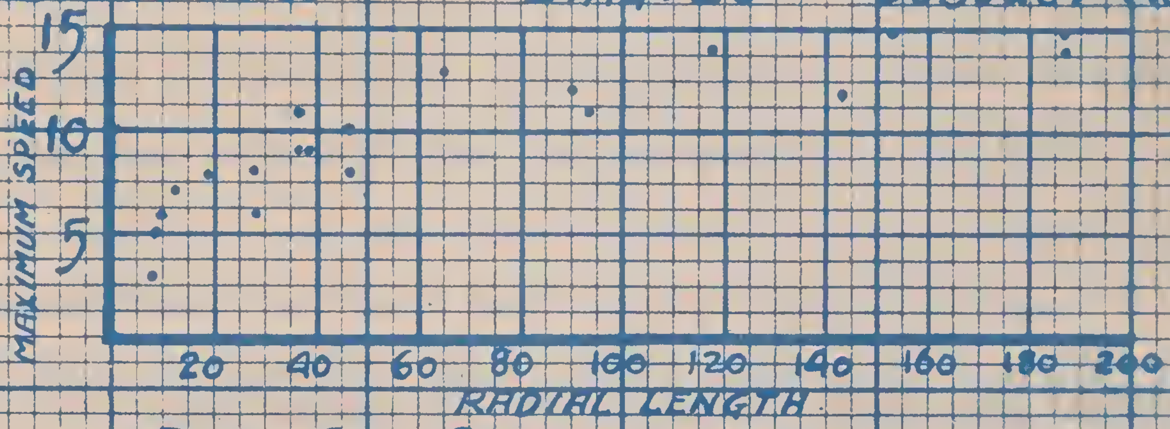
PLATE V



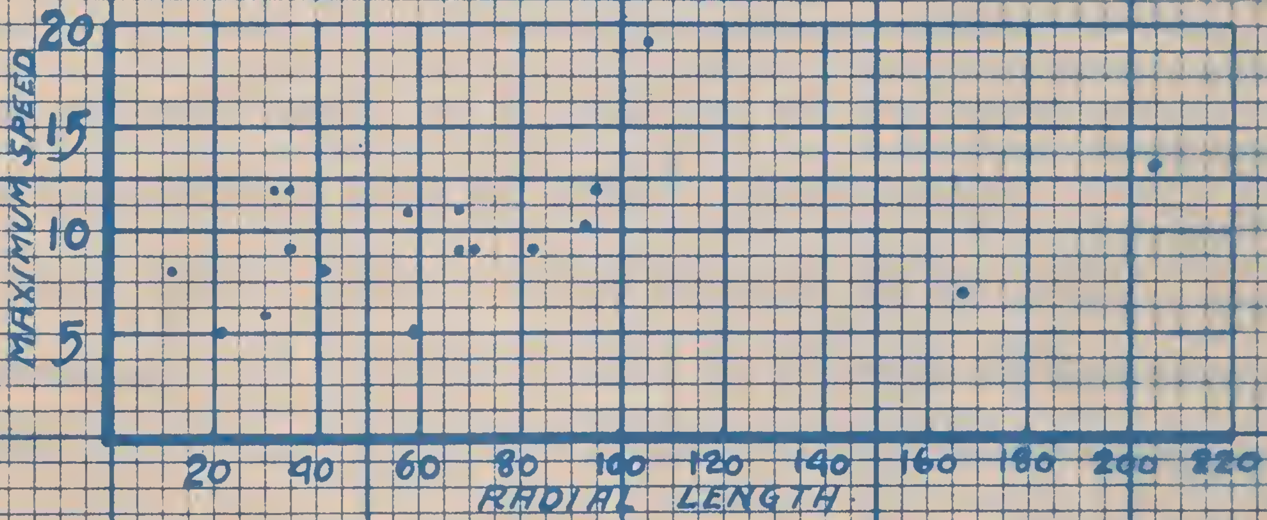
DIAG. 19 - SUBJECT No. 11



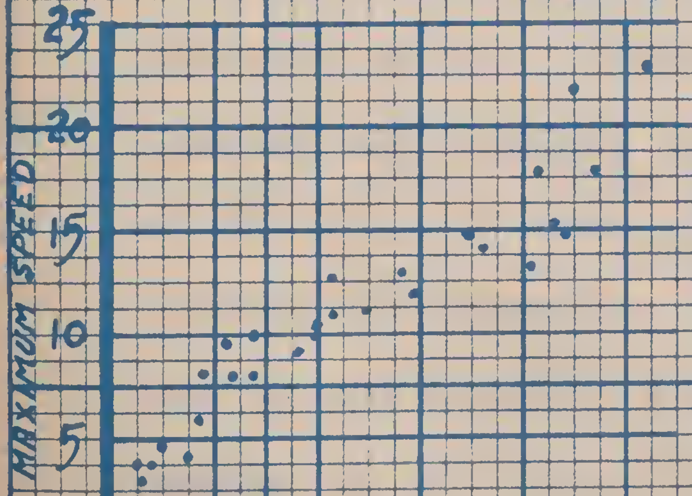
DIAG. 20 - SUBJECT No. 9



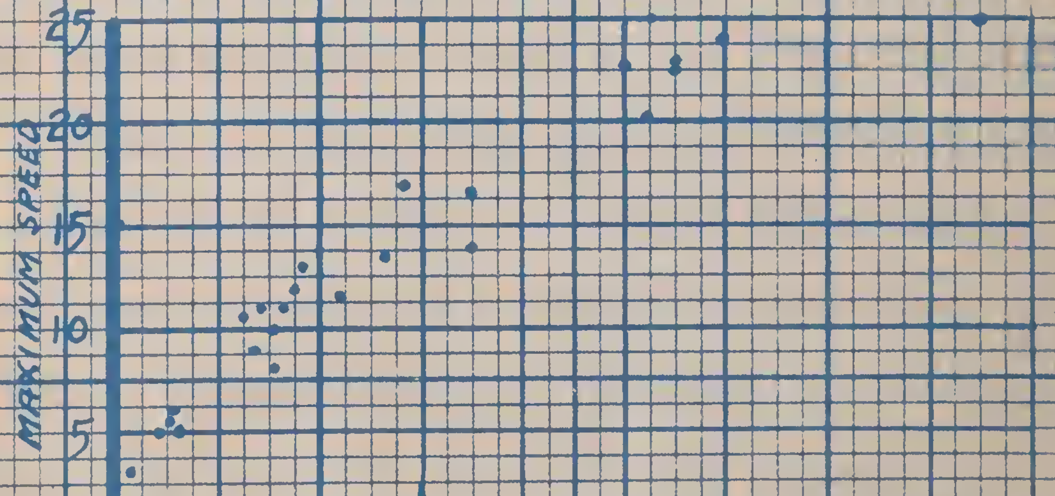
DIAG. 21 - SUBJECT No. 14



DIAG. 22 - SUBJECT No. 18



DIAG. 23 - SUBJECT No. 20



DIAG. 24 - SUBJECT No. 5

SCATTER DIAGRAMS SHOWING RELATION BETWEEN CURVATURE OF THE ARC AND MAXIMUM RATE OF MOVEMENT WITHIN THE ARC.

DIAGRAMS 19-22 - SUBJECTS WITH POOR COORDINATION - INDIRECT OVAL
" 23, 24 " " GOOD " " - WRITTEN WORDS

measures showing a lack of corresponding relationship between the rate of movement and size of arc in the larger arcs as compared with the smaller.

Subject 14 was an older child subject about 12 years of age, whose writing is not characterized by great incoordination (see Plate II and III), but lacks the free flowing movement which we have noted in some subjects. There are some abrupt changes in the direction of curvature, but very little wavering. His chief difficulty seems to lie in letter formation . The diagram 21 shows evidence of correlation of speed and size of arc in the smaller strokes, but in the

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Plate V. Comparison of Poor Writers - Running Oval.
Relation between the radial length of a curve and the speed with which it is made - in ordinary writing.

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larger arced strokes there is a leveling of the speed measures which indicates a comparative lack of direct relationship. This child is a finger movement writer though being trained in the public schools in free arm movement, and has difficulty in fluency of arm control.

The case of a single younger child subject will suffice as typical in the study of this relationship. It was quite difficult to discover in the indirect oval (shown in Plate I and Fig. 15) made by Subject 18, a child of 7 years of age, many representative sections of the line of writing which might fairly be called arcs, as the changes in direction were so frequent as to defy this type of analysis in any complete manner. However careful analysis of a lengthy sample of writing produced the results shown in the correlation table of Diagram 22. The survey of this diagram shows it to be in quite evident contrast to the preceding records. Here there is no real evidence of any correlation between the two categories,the loci of meas-

ures being quite indiscriminately scattered, so that no line of regression can be ascertained and no ratio of correlation computed.

The question remains as to whether this relationship between the rate of movement and the size of the curved stroke is discoverable in ordinary writing, in which there is a complex combination of straight and curved lines and in which at least all the smaller movements are made with some aid, if not the major aid, of the fingers.

It was found more difficult to isolate the curved sections from the complex of movements than was the case in the running oval. This was because the arced portions would change so gradually into approximately straight lines, also the majority of the curves were of such small dimensions as not to afford, even on the enlarged scale of projection used, a ready or exact measurement.

The record of Subject 20 in the writing of the characters, "hen he wakes" was analyzed, and the measures for all the more clear-cut portions made and tabulated. Study of the graphic table of correlation (Diagram 23) shows that the direct relationship still obtains for this subject in his regular writing, though probably not in as marked a degree. The line of regression takes a different trend than was the case in Diagram 14, being similarly placed among the lower and higher measures only, and indicating a slightly different relation between the two scale values as a whole.

The plateau in the line of regression, as compared with that of Diagram 14, cannot be certainly explained until more cases are consulted and comparisons made. An hypothesis may be formulated, however, which will be based on the nature of the written exercise, and the habits of the writer, and which may prove a basis for future investigation. This subject uses arm movement quite freely and thoroughly on the larger swinging movements such as occur in the oval.

In his smaller, ordinary writing, however, he uses the finger movement quite perceptibly, especially on the smaller strokes. It is possible that the difference in the two records is explainable on the supposition that the correlation curves for the arm movement and finger movement are distinctive. It is likely that the predominant use of the fingers in ordinary writing is responsible for the relative slowing down of speed in the medium sized arcs. But we have already noted (p.) that the finger is generally more rapid of movement in the stroke than the arm, and in fact this writer shows his smaller sections up to 30 ø in radial length to be made with a greater speed proportionately than the longer arced parts.

It is more probable that the plateau exists because of the shifting from one set of movements to the other, which would naturally occur in the medium sized strokes. In the use of either arm or finger movement there would be in the case of any individual a lever of definite length and weight operating in a more or less fixed manner. But when these diverse sets of levers act together we have the introduction of new operative elements which may act in such a way as to change the whole relationship. Here indeed is the critical point in the development of coordination.

Subject No. 5 is a fluent writer who has an appreciation of rhythmic movement as well as skill in gaining it. He also makes free use of arm movement on the larger strokes and of the finger movement to a marked degree in the smaller curves. The performance of this subject in the same exercise was studied. Diagram 24 shows a positive correlation between maximum speed and radial length of stroke, with a tendency to a curved line of regression. Although there is a suggestion of a plateau in the middle sized arcs it is not so noticeable as was the case with Subject No. 20 in the same exercise.

Definite experimentation should be planned and carried out along the lines here suggested, but under carefully controlled conditions. The findings here gotten point toward certain conclusions, but these need to be further tested before general acceptance is possible.

The free flowing movement which is characteristic of the writers showing best coordination, is a matter of motor control. This motor control consists of skill in using the members adapted to handwriting as free swinging levers, either alone or in combination. Each of these levers, having a constant length, and momentum, tends to describe any arced stroke of a certain size with the same degree of speed, in general the speed increasing as the size of the arc of movement increases.

This increase of speed is not regular, however. In the cases studied, the majority show a tendency to a smaller proportionate speed on the larger arced sections, and consequently a proportionate increase of time. But a distinction is notable in this respect between the better and poorer writers. The former show a marked tendency toward a regular, constant increment of speed as the size of the arc increases, in contrast with the latter who decrease their proportionate speed appreciably in the larger arcs, and show no very close relationship between the rate of movement and curvature of the line of movement throughout.

In other words, the better writers show a tendency toward temporal rhythm in which arced portions of varying sizes would be made at proportionately different rates of speed and consequently with about the same duration, as contrasted with the poor writers who make a greater adaption of time as a variable. As a matter of fact, as has been noted (p. 120) the average writer does not exhibit any complete kind of simple temporal rhythm in the sense that successive

gether for most efficient results, but just what is the most favorable rate at each stage of the learning process has not been determined. Nor have those factors which affect the speed of writing been thoroughly analyzed and their degree of influence estimated. Some of these have been noted in this investigation and will be here dealt with briefly. There is a marked difference in different individuals in their rate of movement, which is probably best explained as a physiological set, corresponding somewhat with reaction time as to fixity and possibly influenced by a period of habituation. This is possibly the largest factor in the lack of economy, but the question of its extent must lie outside the field of this investigation. To what extent it may be modified by training is problematical.

Good motor control which provides definite progressive movement with no hesitation and is characterized by marked fluency is undoubtedly favorable to an increased rate. The contrast between the child record of Subject 17 in Plate II and that of Subject 1 is typical of the effect of a slow, hesitating, drawing movement on the speed of progress, the former accomplishing each oval in about 35 ∅ while the latter performs the same task in about 14 ∅. In general the adults show much greater fluency in this respect than do the children, and those of the adult group who show better motor control are usually most efficient.

The form which is being constructed is a determinant of the rate of progress. Abrupt reversals of direction are accompanied with periods of rest which tend to destroy momentum, directly increase the time taken and, in the necessity for readjustment, cause loss of speed in the following stroke.

Complexity of letter forms reacts unfavorably on the rate of writing, involving as it does not merely reversals of direction but,

PLATE VI

Number of Subject	between "then" and "he"	between "he" and "wakes"	between "wakes" and "Lucy"	between "Lucy" and "from"	between "from" and "sleep"
1		14		6	
3		25		29	34
4		33	27		23
5_{-1}	4	6	6(0)		7
5_{-2}	20	19			
6		14			
7	15	17			15
8	(?)	26			30
9	(?)	24		16+	24
10	9	26	19		
11_{-1}	19	19	25		
11_{-2}	16	16			
12_{-1}	23	13			(?)
12_{-2}	16	(?)		16	18
13	(?)	(?)		12	14
14	30+	16 (?)		(?)	(?)
15	(?)	28	(?)		
20_{-1}	6	6	11	?	8
20_{-2}	12	26			
20_{-3}	9	21			

MOVEMENT AND TIME OF PASSAGE BETWEEN WORDS

⊓ = PEN LIFTED FROM PHOTOGRAPHIC FIELD   FIGURES IN SQUARES = TIME IN 50ths OF A SECOND.

to a greater extent, compound curves. There is a slowing of motion at any transition point from one curve to another in a reverse direction with the result that a compound curve is made more slowly, other things being equal, than one of simple character. Rapid writers, as Subject No. 12 (Plate III) usually tend to slur over the formal elements in the strokes and reduce all curves to simple forms, with the result that speed is attained at cost of legibility.

An element of economy which has never received adequate attention is one which related, not to the visible product, but to the movement between words. The method of investigation here employed permitted the study of this motion in detail so that the character and direction of the movement could be ascertained for the majority of the subjects, and the comparative amount of time so spent could be computed. The findings in this line of investigation have been compiled in Plate Six for ready inspection. The records are incomplete as to the study of all such spaces in the exercise, and also as to the habitual behavior of any individual, yet enough material is here presented to emphasize certain noteworthy facts. The visible line of writing in the finished product is indicated in each case by a full line, while the movement of the penpoint from the time when it is lifted from the page until it is replaced is shown in a dotted line. The small figures placed in each compartment indicate the amount of time in fiftieths of a second which is spent in the passage from the end of the particular word to the beginning of the next.

Plate VI. Movement and Time of Passage between Words.

Detailed analysis of the exhibits presented in this plate shows a great variety of differences in accomplishing this movement, but

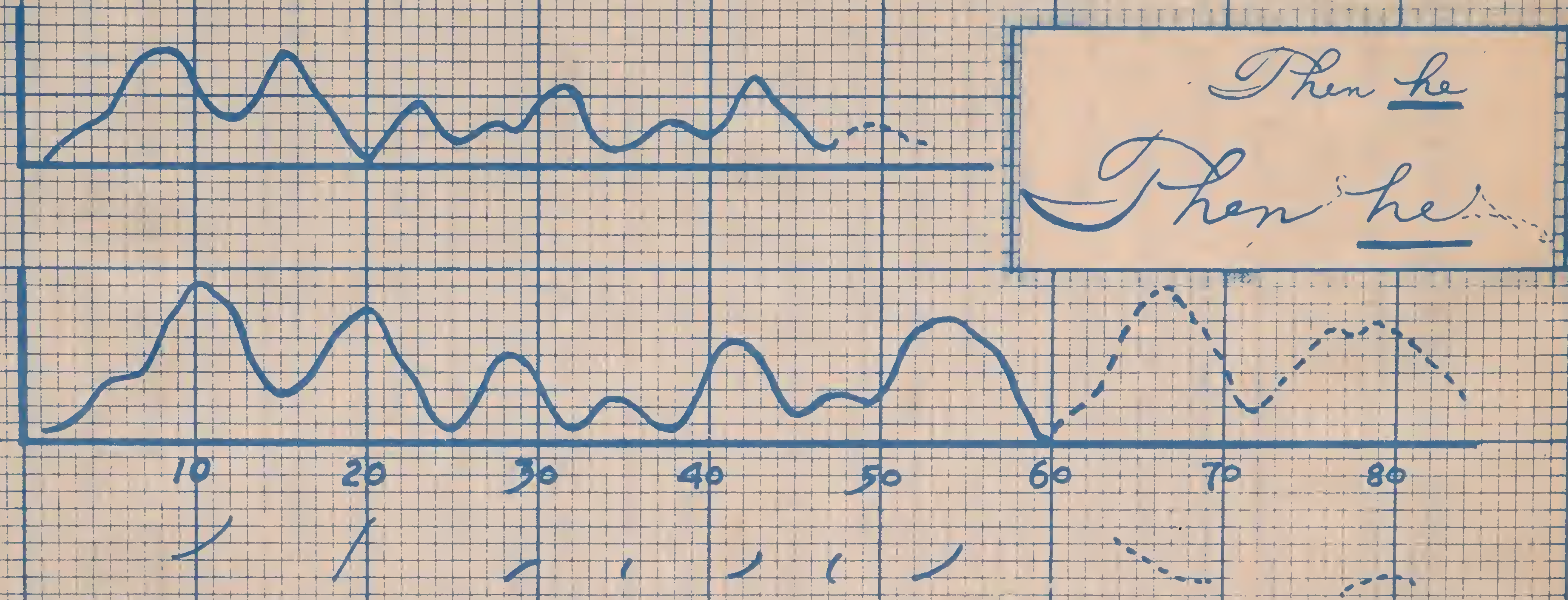
with a majority of the subjects there is evidently a great deal of waste motion. In only a few cases do we find a subject making a direct contact from one word to the next. This is especially notable in the record (1) of Subject No. 5, who has achieved well nigh perfect efficiency in this respect in the exercise under conditions of normal penmanship. Every passage between words is accomplished with a minimum motion and time. He omits the last stroke commonly given to the "s", but makes it in the air instead in the same time as would be ordinarily given to the stroke, so as to make direct connection with the beginning of the "L" so that practically no time is lost in this passage. The same thing is true of the partial stroke between "m" and "h" in the first column. Where a change of direction is required in order to get into position for the beginning of the next word, it is done by a definite stoppage of movement at the end of the final stroke, and the lifting of the pen while making a definite stroke in the air to the beginning of the next word.

The same characteristic is noted also in the record of Subject No. 1, between the words "Lucy" and "from", in the first exhibit of No. 20 in the first two columns, and to some extent in the single case noted for No. 5. Most other exhibits indicate that the subjects had marked difficulty in effecting the passage simply, some making simple loops, evident in the last three columns for No. 20, but the majority accomplishing it only by several changes in direction. In many cases the final stroke of the letter is made with such momentum as to carry the pen far beyond the point of connection, and it must then be brought back into position. This is done quite simply in

the case of Subject 11, but is accompanied with a great deal of wandering in the case of other subjects, for example Nos. 3, 12 and 14.

The time spent by those subjects whose record was computed ranged between practically no waste time to over half a second, while the majority show an average waste of from 15 σ to 25 σ. The significance of this factor as an element of economy is indicated by the record of Subject No. 4 for example, who requires only 45 σ to write the word "he," but spends 33 σ, about 75 per cent of the same time, in transition to the next word. If this transition could have been achieved in 6 σ, as was the case with No. 5 or No. 20, the writer could have saved 27 σ, which, at the normal rate with which he wrote the word "wakes" just following, would have brought him almost to the completion of the next two letters. The instances of which this is typical could be noted many times. <u>It is evident that writing efficiency could be greatly increased by proper emphasis and training in quickness of passage between words.</u>

As to the cause of indirectness of passage so common among the writers no adequate data was collected. It is noteworthy that Subject No. 5 advocates and practices a method of progress along the line which is doubtless responsible for the superior record. This method is described quite well by Freeman, "The Handwriting Movement," pp. 16-17, and may be briefly noted as a free easy movement of the hand by a turning of the forearm on the elbow or muscle pad as a pivot accompanied by an adjustment of the wrist, the forearm being placed at an angle approximately perpendicular to the line of writing. Freeman's concept of the value of this method relates chiefly to letter formation, but it is evidently of value in point of economy as well. <u>The majority of those who waste time in the passage between</u>



DIAG. 25 – COMPARISON OF SPEED CURVES FOR SMALL AND LARGE WRITING OF THE WORD "he" – SEE INSERT – SUBJECT NO. 20

words do habitually shift the arm into a new position between most of the words, but this shifting process is rendered unnecessary in the method above outlined.

Another factor which causes waste of time and motion between words is overemphasis on fluency of free arm movement, which is apt to result in an exaggeration of the length of final and initial strokes, and the describing of various flourishes in preparation for the beginning of the next word. This is quite evident in the case of Subject #3, who is an exponent of an arm movement system of penmanship, and in the formal writing especially of Subject #20 (parts 2 and 3), also the records of Subject #8.

The formal requirement of extra initial and finishing strokes on letters at the beginning and end of words respectively, is evidently an element of confusion, and restrains the free spontaneous choice of movement to establish direct connections.

The dotting of "i's" and "j's" and the crossing of the "t" and "x" would probably introduce similar elements as the passage between words, and would require the same training to counteract the tendency to loss of efficiency.

Diagram 25. Comparison of Speed Curves of small and large writing by Subject #20.

The size of the written form is a factor in economy which cannot be overlooked. The record of Subject #20 in writing the word "he" is evidenced as typical. In Diagram 25 is given a comparison of speed curves showing the effect of large writing, part 1 being the curve for writing of normal size and part 2 relating to writing which was purposely made larger. The word "he" was the exercise here measured. The respective samples of penmanship are reproduced to

show the comparative sizes. The line of visible writing is represented in the solid line of the curve, while the passage to the next word is shown in the dotted section of the curve. The time increase in the larger writing over the smaller, including the movement between words, is about 61%. Other words written by this and other subjects show in every case an increase of time where the writing is larger, though in varying degree. In general this fact corresponds with that before noted (p.126) where the amount of time spent on a stroke shows quite a direct relation to the length of the stroke.

The ability to follow a metronome beat has been discussed (pp.60-61). It was evident from the study of Diagrams 11 and 12 that the attempt to follow a rhythmic beat, although this was timed as fast as could be consciously followed, resulted in a marked decrease of speed. Apart from the question of organization, it is evident that the use of the metronome, or other rhythmic stimulus, may result in the slowing down of the rate of movement in those who are capable of writing well at a much faster rate than the beat permits. In case such an adaptation could become habitual, as some evidence seems to indicate, the use of the beat might result in a marked loss of efficiency. It is probable that some might be aided by a slowing down process which would permit greater emphasis on the quality of form. A beat which would be rapid enough to correspond to the habitual stroke of an average adult would probably be too rapid to be consciously followed. Among younger children, who need the stimulus to quicker and more direct movement, such a beat might prove advantageous until they reached a stage of ability where the imposed rhythm would act as an actual hindrance to further

progress in speed efficiency.

Habituation.

The distinctive difference in the behavior of the various subjects, as above discussed, may for the most part, as far as the data presented goes, be quite accidental in character. It is indeed possible that the record gotten for any subject may not be truly representative of his general behavior, since any of his exhibits may be quite different from any other which he might make. In the majority of the cases thus far dealt with the validity of the findings have not depended on the maintaining of a form of characteristic behavior by the subjects. Nevertheless the question arises in connection with the learning process: to what an extent may one expect to find any individual remaining constant in his behavior; to what degree is this factor an element in the total writing process, or in particular phases, and how may it be effected?

One commonly speaks of a person's "style" of writing as though it was quite distinctive, and though his judgment is usually formed as a result of casual inspection, rather than minute and detailed comparative measurement, there is no doubt a tendency for particular individuals to develop an habitual form of writing which shows itself in similar shapes and sizes of elements, and peculiar construction of forms, which serve to differentiate his product quite effectively from that of any other writer.

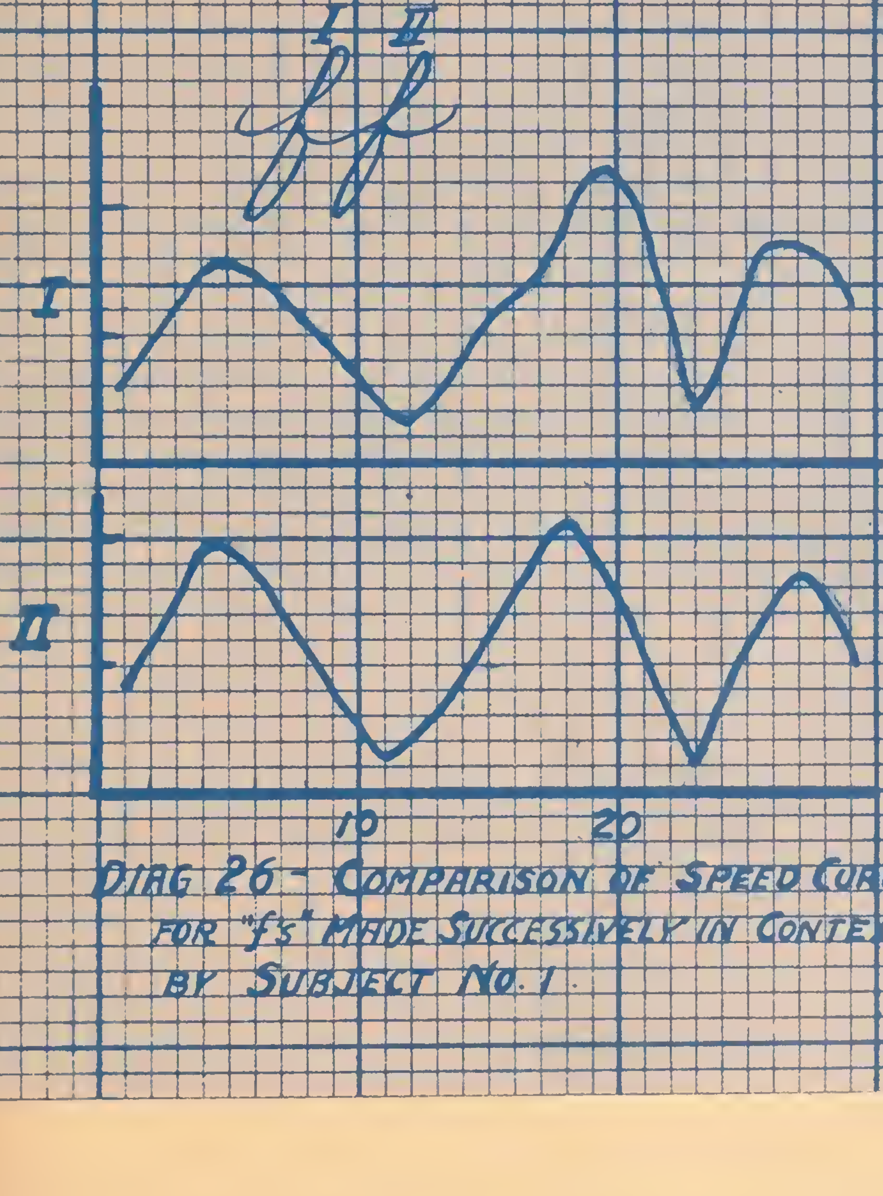
The question that here concerns us is whether or no the individual tends to show the same time relationships in the construction of similar strokes, letters and words. Some typical examples are here compared with a view to noting the degree to which

speed curves for movements are related, and, if possible, point out some of the factors which influence this relationship.

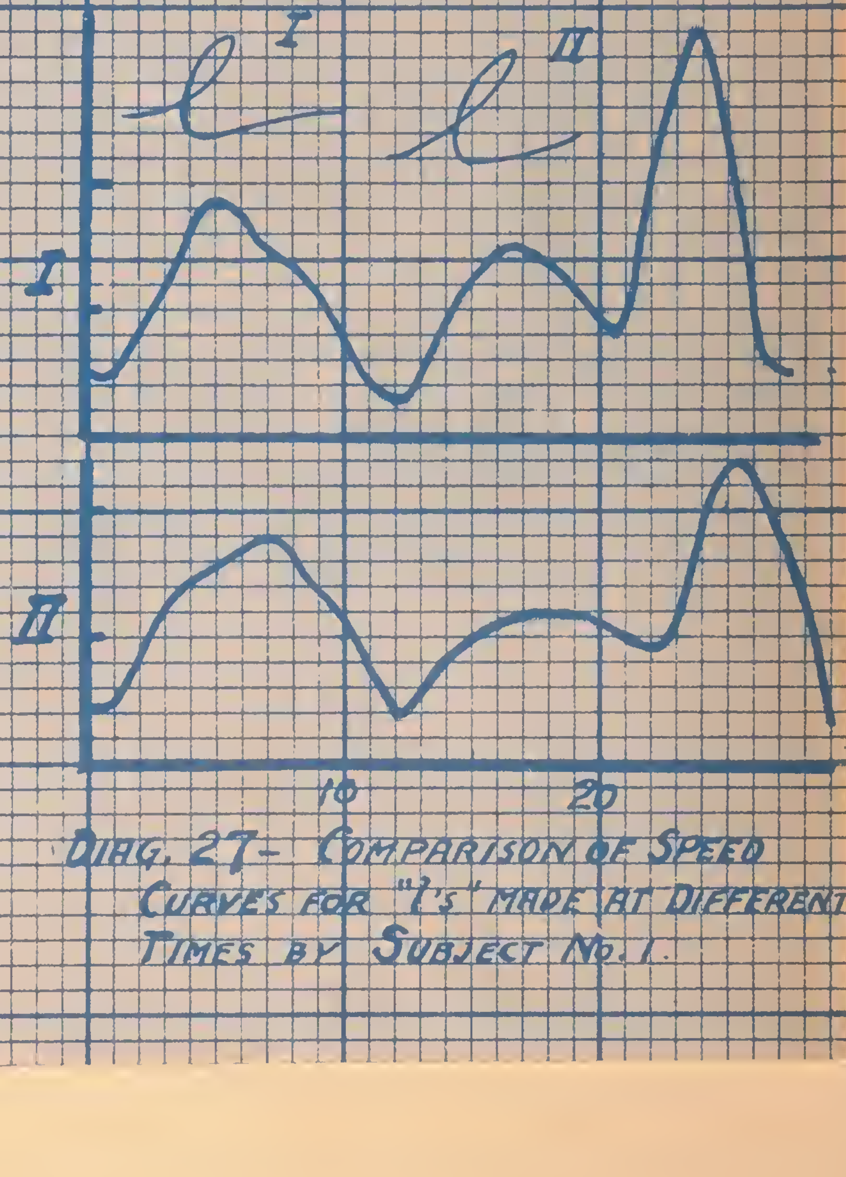
Referring to Plates I and II it is noteworthy that the speed curves and written strokes are quite consistent throughout for any individual, at least in the majority of cases. Subject #2 does not make successive strokes or ovals in similar form and his speed curve for the exercise shows marked diversity in the organization of the elements which should be similarly constructed. In the same class fall Subjects 9,10,11, and 12, while 3 also shows this characteristic to some extent.. Those who show a marked tendency toward giving each successive comparable group the same speed and time emphasis are 1,4,6,7,8 and 20. Among the children 18 and 19 are very irregular so that nothing can be certainly prophesied as to the probable nature of any following stroke or group of strokes either as to its specific rate or distribution of speed. In the case of the child #17,however, the subject seems to have acquired quite a distinctive type of control over the up-stroke,and to encounter the same type of difficulty on all down strokes.

In this manner all of the subjects may be analyzed, with the result that some poor writers are found to show indications of habituation as surely as the good writers, while some show little consistency of performance. Some individuals show a persistence of behavior in certain phases, while totally unhabituated in others. The children gradually develop the habitual performance with age, The good writers generally show a marked tendency to habituation.

In ordinary writing the same letters and words as made at different times by the same individual should reveal the existence and degree of the tendency of an individual to habituation. Typical



DIAG 26 – COMPARISON OF SPEED CURVES FOR "f's" MADE SUCCESSIVELY IN CONTEXT BY SUBJECT No. 1



DIAG. 27 – COMPARISON OF SPEED CURVES FOR "l's" MADE AT DIFFERENT TIMES BY SUBJECT No. 1.

examples are here presented, showing the analysis of comparable forms, and the process by which they are made.

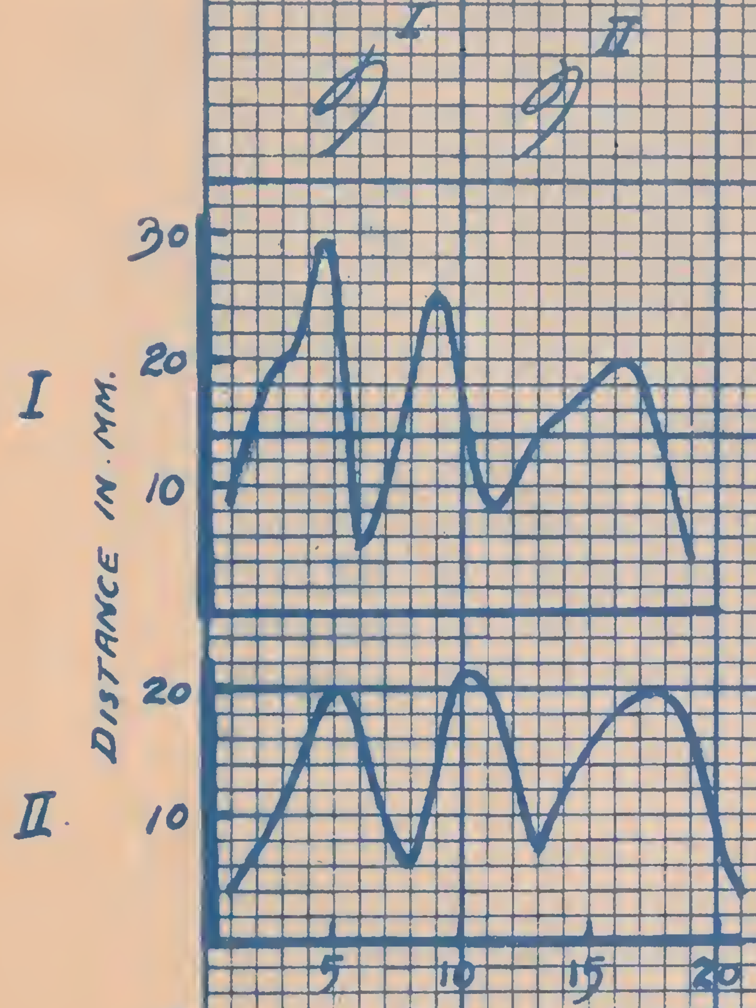
In Diag. 26 are shown the speed curves representing the rate of movement of Subject #1 in writing two successive "f's" in the word "eiffel" as reproduced in the corner diagram. The curves I and II represent the two "f's" respectively. Neither the curves nor the letters are identical in form, yet there are significant similarities. The summary table of measures are here given.

Table 21.
Comparison of Measures for Two "f's"

		STROKES 1	2	3	Ave.
Duration in σ	I.	11	12	6	9.7
	II.	11	12	6	9.7
Length in mm	I.	110	155	85	117.
	II.	120	145	80	115.
Max. Sp. in mm	I.	16	22.5	17.5	18.7
	II.	19.5	21.	17.	19.2

The time in σ on comparable strokes is the same in I and II. The strokes are found to correspond quite well as to length, but differ slightly as does the maximum speed also. In II the first stroke is longer than in I, but is made in the same length of time. Consequently it is made with a greater maximum speed as compared with I. In the second and third strokes the reverse is true. The form of the second stroke in I is more skewed than the corresponding stroke in II.

In Diag.27 is shown the comparison of curves derived from the records for making the letter "l" by the same subject on two different occasions and in different context. In this case the similarity is not as great as was true of the two "f's" either as to form, duration, rate of movement or organization. The first and third strokes are the same as to duration in the two letters, but the second varies noticeably. None of the strokes is greatly variant



DIAG. 28. COMPARISON OF SPEED CURVES FOR THE FIRST THREE STROKES OF "m" MADE AT DIFFERENT TIMES BY SUBJECT NO. 1.

in length from its compared stroke. The maximum speed differs markedly in the two for stroke 3, the longer receiving the greater speed. In general inspection would reveal that these two curves relate to the same form. Such variations as occur in the speed curves are clearly traceable in the written forms, and vice versa.

In the same way the first three strokes on "W" are compared with the first three strokes of "M" as written by the same subject. The table of measures is given (Table 22) as well as the speed curves. (Diagram 28)

Table 22.

		STROKE 1	2	3	Ave
Duration in ø	I	6-	5	8	6.3
	II	8-	5	8	7.
Length in ø	I	98	85	110	97.7
	II	85	80	115	93.3
Max. Sp. in ø	I	29	25	20	24.7
	II	20	21	20	20.3

This writer has a tendency to reproduce similar strokes in about the same length of time. When comparable strokes are different in length they are executed by adaptation of wither or both the time and rate of movement. When the time factor is constant in the two cases there is a direct rationbetween maximum speed and the total length of stroke.

The comparison of the records for words, as written at different times by the same individual reveals some interesting facts with regard to habituation. These records are placed together in Plate VII for ready comparison, all relating to different curves for the word "he". The numbers of the subjects are placed opposite the groups of curves representing their record. The actual writing for these records is shown in Plate III (p.115).

In the case of Subj.#1 the first exhibit(i) was made more rapidly than the second (ii) with the result that the maximum speed

was noticeable greater than in (ii) while the average duration was less, especially marked in some strokes. Practically all the increase in speed in (i) as compared with (ii) is gained within the first three strokes, the remaining strokes being made in approximately the same length of time in each case, a clear instance of habituation in time interval for a particular type of stroke.

The distribution of speed in the various strokes is perhaps as noteworthy for comparative purposes. The second, or down-stroke, on the "h" is in both cases retarded in speed at a certain point in its initiation, and also again near its completion. The third stroke shows even distribution in both cases, and both show a characteristic retardation in the middle of the fourth stroke. Stroke five is made with practical identity in speed distribution, Stroke six differs slightly and stroke seven, while differing in the middle shows the same evenness of speed placement in the beginning and end. Evidently these speed curves are representative of the work of the same subject, engaged in the same process on two different occasions, and resemble each other more than they do similar portions of the word as represented in curves for other subjects.

Subject #12, the rapidity of whose writing is remarkable, has no clear differentiation of strokes in either case, and the organization of (ii) is quite different from that of (i). The distribution of speed within comparable units is likewise different. This subject, though showing some small features of habituation, especially as to rapidity, reveals no definite system of temporal organization. This conclusion also holds true of other comparable records by the same subject.

Subject #11 shows a much better and a more definite organiza-

tion than #12, with some evidence of habituation in organization. The respective strokes are identifiable in the two records, but there is a great deal of variation in the maximum and minimum speeds and the time given to comparable elements in the last four strokes of the exercise. The passage to the next word is effected quite differently in the two cases. Some stroke curves are similar to a degree, and there is the same slight rest at the end of the second stroke, but otherwise neither record is typical of the other in any complete sense.

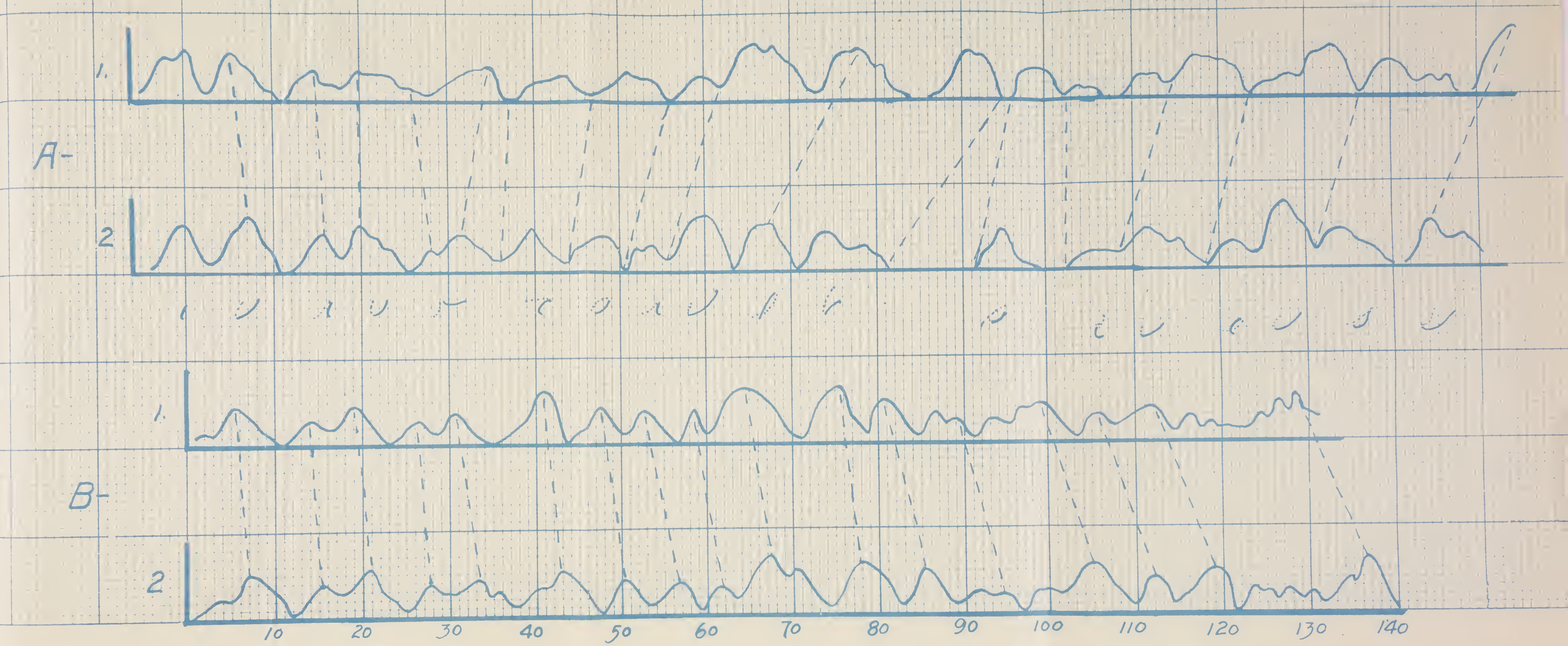
Marked habituation is evidenced in the case of Subject #13. The records are so near alike as to require no specific device for identifying the comparable strokes. In both cases the time spent on respective strokes is about the same throughout, and the organization of strokes, distribution of speed, and the maximum speed are about the same. The subject is a remarkably good writer, with a consistent performance of a free, fluent movement, though a child of about 15 years of age.

The comparison of records for Subject #20 reveals another clear case of habituation. The four exhibits given are respectively: (I)Speed curve for the writing of "he" in ordinary penmanship. (II)Curve for writing of "hen" in ordinary penmanship. (III) Curve for the writing of "hen" in large style and (IV) for the writing of "hen" while following an imposed rhythm. (p.124) In all portions which are directly comparable;i.e.,the characters "he" in all cases and "hen" in the last three, there is distinct evidence of habituation. The lower speed in the last two cases is due, hypothetically, to time and rhythm factors incident to the conditions (pp.124,145.). In all cases the organization of

strokes is distinct and quite similarly effected for similar strokes. The time devoted to similar strokes in (I) and (II) is practically identical, as are also the degree of and the location of points of maximum speed. The same may be said when (III) and (IV) are compared, though these are hardly comparable since they were made under different controls. The writer persists in his habitual performance to a remarkable degree even when changing the size of his penmanship, or when making the attempt to follw an imposed rhythm.

The curve of speed for Subject #20, though somewhat slower in movement, resembles the curve of Subject #13 so much that they might easily be mistaken for one another. This fact raises the question whether it is not possible, and indeed, likely and desirable that good writers should develop quite similar habits of speed and organization when performing the same exercise. Just what allowance should be made for individual differences in this respect is at present problematical and calls for special investigation. It is possible that efficiency of penmanship instruction is decreased rather than increased by a demand that the pupil attain a certain standard or formal style. However this may be, it is quite certain that the individual pupil should attain certain fixed habits of movement both as to speed and organization, and that he should, within certain limits, maintain a certain characteristic behavior in performing the same exercise at different times.

All efficient penmen here investigated have this tendency well established, while the poor ones do not, at least in the several elements of duration, speed and organization as well as



Diag 29 - Comparison of Earlier (1) and Later (2) Writings of the Word "[illegible]kes" by a Poor Penman (A) and a Good Penman (B).

form. No instances have been discovered in this investigation of any poor writers who have definite habits established in this way so that any prophesy can be safely made as to the characteristics of any stroke on the basis of its theoretical similarity to any preceding stroke. Whether such cases do exist is problem~~s~~atical.

Two typical cases are given in Diag.29 which show quite clearly the contrast between the records of the unhabituated poor writer and the habituated good writer. Part A shows two speed curves for the word "wakes" as written at different times by the same subject(#9), a poor penman. In Part B are given curves for the same word as written twice by Subject#10, a very good writer. In both parts the corresponding points in the two trials are joined by the dotted line. In case there were perfect correspondence between the two records as to duration these dotted lines would, of course, be in parallel. Examination reveals that the lines in (A) do not exhibit this characteristic, while those in (B) do to a marked degree, the chief variation being due only to a slight diminution in speed in the second record as compared with the first.

When the individual units of the exercise are compared in the two cases in (A), and also the two cases of (B) the comparative irregularity of the former two is at once apparent. With the first subject comparable strokes very seldom resemble one another closely in the two trials, in either distribution of speed or duration, but in (B) the record for each stroke is quite easily identifiable as related to that of the comparable stroke in the first exhibit or second exhibit by the

same writer. In many instances the curves for particular strokes in (B) are almost identical, except for slight modifications.

It is very difficult to deal with habituation except as it is treated in relation to the isolated components which go to make up the total movement, and as these are analyzed at length and in detail, with thorough experimental controls. But even from such a summary investigation as is here made it appears to be a most significant factor in differentiating the good and poor writers.

SUMMARY CONCLUSIONS:

1. The method here devised for analysis of temporal characteristics of the handwriting movement has proved itselfremarkably successful. It has been found possible to analyze speed relations to a very minute degree, and with a very high degree of accuracy. It has also been found applicable to the solution of a great variety of problems which have not been susceptible to adequate treatment heretofore.

2. Good writers show a much more even type of speed distribution then do the poor writers, especially the younger children. In general this type of organization consists of the recognition of the stroke as a unit of movement, a steady progression throughout the line of writing with no abrupt changes in direction, and a gradual increase in speed within the stroke to the point of maximum speed, which is usually placed near the middle of the stroke, followed by an even decrease of speed.

3. Temporal rhythm, in the sense of an ability to execute successive movements in the same length of time, does not seem to be very significant in distinguishing between good and poor writers. The adult manifests a higher degree of rhythm, on the average, than does the child, but the individual child may rank very high in this respect.

4. In the execution of simple, repetitive forms there is manifested a marked tendency to rhythm, but the written word forms shew a much more marked deviation. All writers tend to devote unequal amounts of time to the various strokes when those strokes are of different length and form.

5. A marked interactive relationship was found between the three variables in the stroke; duration,maximum speed and curvature. Length of stroke was found not to be greatly significant in itself, since a stroke is seldom composed of a simple arced curve but rather a complex of curves of different radial lengths. When the line of writing was thus analyzed into its curve elements it was found that the maximum speed for any arc would tend to be in direct relation to the size of the arc as expressed in degree of curvature. In general, however,the maximum speed does not increase in exact proportion to the curvature, indicating a time adaptation, or increase of duration, as the radial length of the arc becomes longer.

6 A distinction was found between good and poor writers in this relation,however. The good writer tended to keep the time more nearly constant by varying the maximum speed within an arc in proportion to its curvature. The good writer also showed a closer relation between the maximum speed and the size of the arc, with fewer exceptions and a more constant performance than the poor writer, indicating the establishment of habitual relations between the three variables.

7. Children show clearly the lack of any definite habituation in establishing relationships between these variables, at least in the earlier school ages.

8. The findings point quite strongly to the fact of such a relationship when using finger as well as arm movement, the former being adapted to the construction of the smaller arced curves so frequently demanded in ordinary writing, while the latter can best be employwd in the larger curved movements. The need for harmonious cooperation of the two is at once apparent.

9. The fluency,freedom, and smoothness of movement, which characterizes the good writer generally, is the fundamental "rhythm" of handwriting. It is due to the unhampered interaction and coordination of the fingers and arm as free swinging levers, and a ready control of the motor elements at every instant, so that there is a definite relation between the form being constructed and the temporal phases. Although two movements may be given different duration, in absolute measure, the difference is in regulated proportion.

10. The following of an imposed rhythm, when successfully accomplished is effective in changing the speed and time distribution of the various strokes, from that which is ordinarily used. The writer tends to equalize the time spent on successive strokes. The rhythm is apt to result in the slowing down of the rate of writing for the rapid writer. When a stroke is made more slowly than is ordinarily done in regular penmanship, in the adaptation to the rhythmic beat, irregularity of speed distribution is apt to result, with evidences of incoordination. The rhythm should be very carefulyy adapted to individual requirements, therefore, lest, in the speeding up of part of the group, with a consequent gain in facility, the remainder of the group have imposed upon them a handicap of slow speed which will in turn affect the form harmfully, as well as induce poor habits of economy.

11. Various factors which make for time economy are: coordination, simplicity of letter form, and facile, direct movements between words. The latter was found to be interfered with greatly by wrong habits of shifting the arm, superfluous strokes, extremely free and flourishing movements and unavoidable crossings of t's and x's and dotting of i's and j's. Large writing is made more slowly than small writing.

12. Good writers exhibit a tendency to fized habits of organization in time and speed relationships which is not characteristic of the behavior of poor writers.

RECOMMENDATIONS FOR THE TEACHING OF PENMANSHIP WHICH ARE SUPPORTED BY THE FINDINGS OF THIS INVESTIGATION.

Rhythmic control of penmanship movement, through the use of the metronome, phonograph,etc., should be employed judisiously and carefully. There is danger of securing too great a unanimity of behavior in a group with consequent loss of originality. Each individual has his own natural "set" or adjustment for rhythm, and while it may be possible to habituate an individual in an artificial rhythm, it is questionable whether this could be attained without interfering with deep-seated controls. If possible the rhythmic beat should be adapted to the particular individual needs.

One who has already developed rhythmic habits or abilities is not directly benefitted by a rhythmic drill. In fact such an individual is apt to be hindered by such drill unless it is at least as rapid as his natural rate, and simple enough to be followed readily.

Quite early in a child's experience in constructing penmanship forms a rhythmic beat or count should be used as a guide in the recognition of the requisite units of movement, or strokes. This exercise can be effectively used in constructing written word forms, as well as in simple repetitive forms, and may consist of a fairly regular emphasis on each stroke, later followed by similar quickened drill with the emphasis on the up-stroke only, as the child improves. This type of drill will aid in hurrying the movement within the stroke so that it will be written, not drawn, and will, if carried far enough, prevent the tendency later on to slur over the respective strokes.

Those who have difficulty in taking on an imposed rhythm in this simple form should receive individual attention. Their deficiency

may be due to the fact that the beat is too rapid or too slow, or the child may not have the kinaesthetic basis for constructing or following a rhythm.

This simple early rhythm or count may give way to more complex and rapid rhythmic drill as the child comes to the place where the forms are clearly in mind, and habits of stroke differentiation are well fixed. The drill should now emphasize speed, but care should be taken that quality does not suffer by too great an emphasis in this respect. A child should be excused from such drill when he has built up speed habits which no longer require the stimulus of the rhythm, or when the rhythm that must be used for the group tends to retard his movements lest he build up poor habits of organization, and become habitually slow in movement.

Most, if not all rhythmic drill, at this stage, should be in the following of a rhythmic stimulus while constructing simple, repetitive forms. It is not adaptive to the written word. The The same forms should be constructed in the same manner, in the same time, and with the same speed emphasis and distribution. The time should be gradually speeded up, as fast as the quality of penmanship will bear it, until,the beat is as rapid as can be consciously followed. This type of drill should effect several changes. It should aid the child in facility. It should give to him fairly definite habits of temporal control, so that he will learn to construct similar strokes in approximately the same length of time and with similar constant form, hence with about the same maximum speed.

Drill may be given in constructing similar forms of different sizes with the same time rhythm. These should not be mixed at

first, so that, for example, a large oval is followed by a small oval, and this again by a medium sized oval, until after facility has been gained in writing a group of each size by itself. The emphasis must constantly be, not on slowing down the speed on the small form so as to equalize the time taken with that of the large form, but on quickening the speed on the large form so that it may be constructed in approximately the same length of time as the small. This control of extremely rapid speed in the larger curves is a marked characteristic of the good writers and should be encouraged by every means possible.

It is doubtful indeed if rhythmic drill can be used very extensively with the written word forms in building up proper habits of speed and rhythm as here suggested. The complexity of these forms, in most cases at least, defies any clear cut arrangement in rhythmic groups. Until this can be done with fair certainty it would be better to place the entire emphasis in rhythmic habituation on comparatively simple, repetitive exercises which involve all the elements found in ordinary writing, but in a rhythmically regulated succession. Simple word forms as "mem", "nun", etc. may be effectively used as also may the repetition of a letter which readily receives the rhythmic beat. The object of such drill muct be, not habituation in putting the same amount of time on each stroke, but in attaining the utmost possible speed, consistent with quality, in the larger strokes, and constancy of speed and form in similar strokes.

After the learner has attained good coordination ability and has learned to clearly differentiate the respective strokes, exer-

cises should be given which will tend to decrease the amount of time given to rest at the end of strokes. The learner now needs to recognize the continuity in the whole line of writing rather than to consider it as a combination of separate strokes. To this end he must learn how to accomplish reversals of direction and to round the small curves smoothly and accurately, as well as rapidly.

The pupil should receive regular drill in free control of all muscles naturally used in writing, especially the finger and arm muscles. There should be harmonious cooperation of all motor factors in the construction of the various sized strokes and parts of strokes called for in ordinary penmanship. The rigid emphasis on arm movement and the exclusion of the functioning of the muscle groups of the fingers and wrist does not find justification in scientific evidence. It seems essential for the proper construction of the smaller movements that finger control be built up instead of being eliminated and that the writer should enjoy a free controlled movement of all involved muscles, instead of being hampered by needless inhibitions. The result will be a rhythmic flow of movement not to be attained by the selection of one set of muscles and the artificial elimination of the other.

The writer should early acquire habits of direct passage between words. To this end he should be taught to place his forearm in position perpendicular to the line of writing at the middle of the page, and move the whole forearm steadily along the line of writing, moving on the muscle pad or elbow as a pivot, and making such adjustment in the wrist as may be necessary to

keep the written line straight. By this method the pracgice of lifting and shifting the arm will be avoided. The writer should also be trained to pass directly to the beginning of the next word, by avoiding all useless strokes and flourishing movements.

All laws of method for the fixing of definite habits should be earnestly followed. Much poor penmanship, if not all, is due to the failure of the learner to acquire fixed habits of time distribution or organization. Possibly there are great individual differences in the ability to take on such habits, but most cases will yield to careful, patient and persistent treatment, especially if individual attention is received to any adequate degree, and no variations of drill are permitted as well as no wrong practise in the daily school work in other subjects.

In view of the fact that little of the actual penmanship instruction given in schools gives adequate attention to individual day-by-day needs in the way of habituation, but on the contrary, permits the learners to constantly repeat their mistakes while struggling with new material, some effort should be made to effect a reorganization which will permit the diagnosis of the faults of individual pupils or the group and also effective drill in the particular fault or faults discovered.

Since most of the faults of organization, movement and habituation manifest themselves in the samples of writing it is clear that they might be discovered had one at hand the requisite indices for such diagnoses. Such indices are suggested in the following section, but these need validation and further experiment in practical application. In this connection also the

organization of instruction must be such as will provide the most efficient treatment; probably some form of grouping during the period of drill, so that all those with a common fault will be seated in the same section and working with a definite objective.

DIAGNOSIS AS AN AID IN PENMANSHIP INSTRUCTION.

It is undoubtedly true that much time is watsed in penmanship instruction through the common method of merely teaching the subject, instead of teaching the special functions of which the skill of handwriting is composed.

In a typical classroom the pupils exhibit a variety of ability in penmanship. Further than this some are very good, if not perfect, in one or more of the functions going to make the total of writing ability while persistently weak in other functions. Other pupils of the group are notably deficient in the former functions and good in others. The question naturally arises: why should the child be instructed fay after day in general penmanship without recognizing and providing for the overcoming of individual faults? Undoubtedly many children drill for years in general exercises in penmanship, but because they have never criticized their own product adequately, or had their attention called to their particular defect, they are constantly embedding themselves more deeply in the wrong habit. Penmanship instruction, so-called, becomes for them an interference rather than an aid.

By drill on special functions general interest should be increased and ability improved so that appreciable gain will be

made by the pupil in a comparatively short time. The teacher should find herself with a specific task of supervision rather than in charge of a matter of routine.

The scheme of diagnosis here proposed rests on the theory that individual defects of form and movement as well can be discovered by a brief inspection of the written product, and recommendations for treatment made which will prove effective. An instructor may, then, look over the samples of the children's writing outside of school hours and come to the penmanship class fully prepared to direct the class since she knows what are the particular faults of the class as a whole, and of indiwiduals, which must be corrected.

The specific functions which are essential to good penmanship may be listed as follows. Each will be described and illtstrated with the expectation that the reader will learn to differentiate the faults common to these functions. Other faults might be noted such as unevenness of line, but these are probably by-products of those here noted..

1. Speed of Writing. Speed and Quality should progress together. The child should be trained as rapidly as possible to accelerate his movement in so far as he can keep his form up to par. Extreme retardation in speed coupled with good penmanship is to be deplored as a continuous practice. On the other hand undue emphasis on speed, as in the following of a very rapid rhythmic count, can result only in a neglect of requisite quality and consequently a poor product. The faster writer is often the better writer because his attention has been set free from the purely mechanical features of the process and can concern it-

self with the more intimate aspects of the form as need arises. A real test of writing must therefore take both of these factors into consideration and note their relation to the norm for the age or grade in order to make a helpful analysis.

2. Quality. This is a general term, covering the general appearance of the written form, and while valuable in a general survey in terms of scores made on a standard penmanship scale, can more properly be broken up into specific elements dependent on the particular functions of the learning process. One should consider consistency of quality in the daily work of the school as well as in the penmanship drill exercise or test. The emphasis on speed during a test may serve to affect the quality harmfully, but commonly one would expect to find the daily work of comparatively inferior quality unless general ideals or habits have been acquired.

3. Habituation in Letter-form. Any defect of penmanship may affect the form of the letters involved, consequently it is difficult to isolate this defect from others which are present. Defective form attributable to poor imagery of the form of the letter can scarcely be distinguished by inspection of the writing alone from that due to motor inability to construct the form as imaged. In view of diverse demands for form which obtain in the various systems of penmanship instruction there is also some disagreement as to what constitutes defective letter form.

A distinction which is fairly clear, however, refers to habituation. (1) Does the pupil's writing show that he has no clear idea of the definite form which certain letters should take? This

can be discovered by noting whether or no the child generally uses a variety of forms for the same letter. For example, in Figure 20(part 1) the child evidences no clear habituation. No

1.

2.

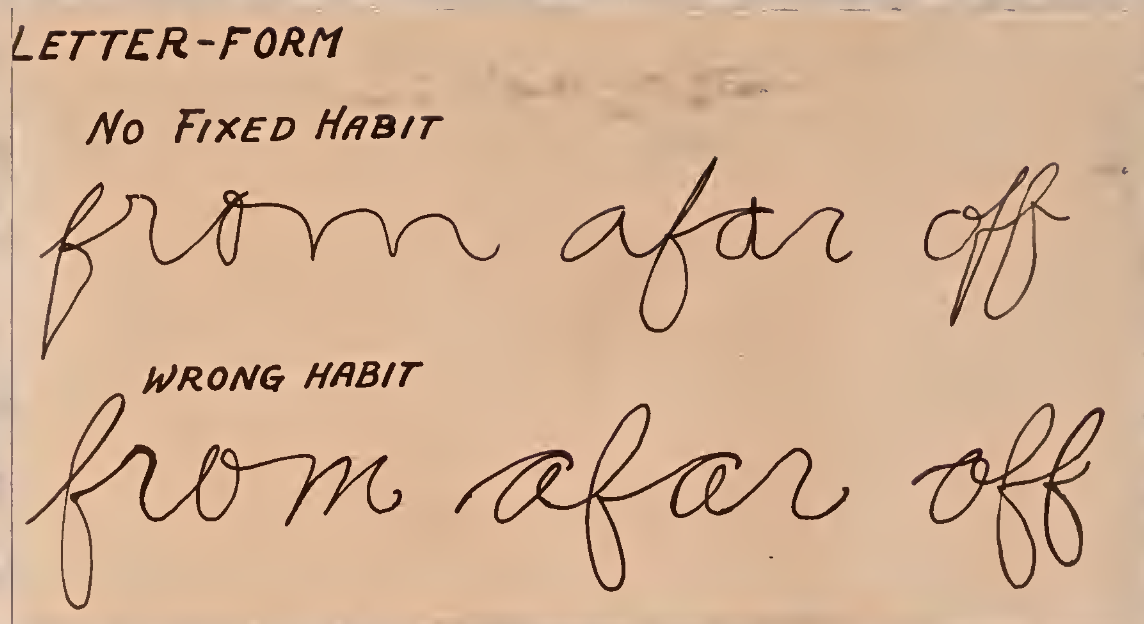


Figure 20. Samples of Penmanship Showing Defects in Point of Habituation.

two f's agree as to form though there are four in the sample. The same fact is true of the "a" and the "o" as well as the "r".
(2) The second question is: Does the child's written product reveal the fact that he has formed a definitely wrong image of form. In part 2 of Fig.20 is found an illustration of writing in which defective forms are consistently repeated so as to cause one to infer that the child is becoming habituated in wrong forms.

What is needed in both cases evidently, is a positive emphasis on the correct forms, chiefly through the method of perception and imitation, until the correct image is gotten. It is difficult to undo the effect of long continued wrong practise, and it is perhaps equally as difficult to get a clear image before some learners who seem to lack any kind of permanent visual or kinaesthetic imagery. It is quite common to find those who

show a makked defect of each type with different letters, calling for very specific drill. If a child is able to fix a definite correct image of any of the letters it is evident that it will be possible with the right kind of training for him to fix the correct image of all of them.

4. Slant. This is an important element, but is not wholly simple since several different errors of slant are common. One of these is (1) a generally wrong slant, habituated throughout. Just what may constitute such a wrong slant is disputable. There is general agreement that the medium forward slant is best probably for both legibility and movement, but whether a vertical or slightly backhand slant will be called defective depends on local emphasis. Extreme slants, either forward or backward, such as these shown in Figure 21 (part I), are doubtless types of defect which which should be remedied if possible.

A second error is (2) where the mixed slant is used (shown in part II of Fig. 21) in which no single slant prevails. The individual letters, tall or short, are made with different slants. This defect occurs in all degrees and is readily recognizable.

The third defect under this head is (3) where the learner gradually passes from good slant to extreme forward slant as progresses along a certain section of the line. Sometimes this section is comparatively short (½" to 1"), and in other cases it is the length of the written line. This type of defect can be readily differentiated from the first in the fact that there is present a certain degree of good slant at periodic intervals. It can also be distinguished from the second in the fact that the slants are not mixed within the words unless by a gradual

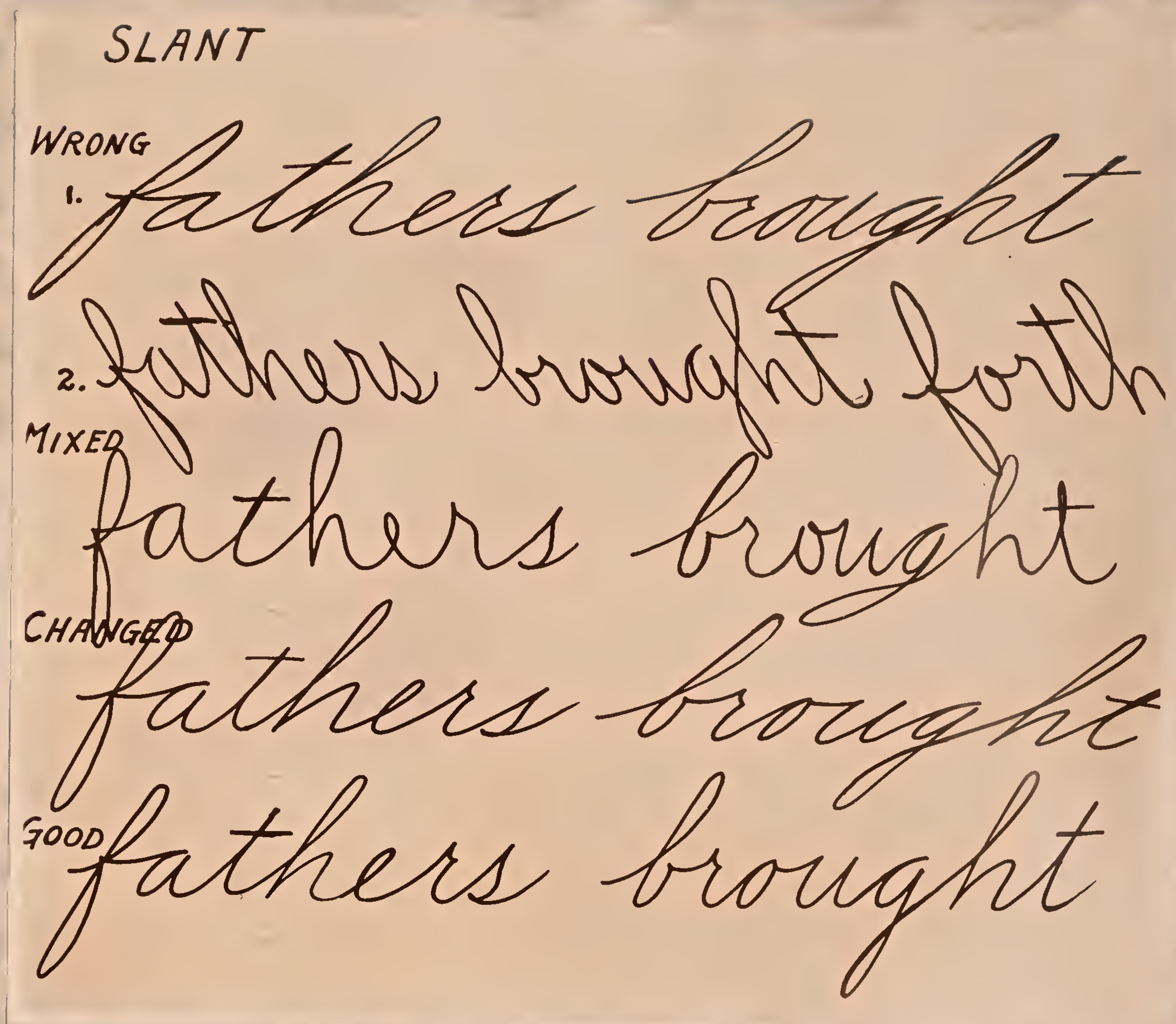


Fig. 21. Samples of Handwriting Showing Defects of Slant.

change.

The first type of defect may be due to the position of the writer, or the way in which the arm or hand is held, or the way the pen is grasped or the way the paper is placed. Or it may be due to the fact that the learner has never imaged the best type of slant, or realized that his writing was in error at this point. The second defect is usually due to an awkwardness of adjustment or a defective image and is usually coupled with incoordination. The third is due entirely to the method of progress of the hand along the line, and a failure to make proper arm and wrist adjustments in passage. In this case as a rule the arm is pivoted at the elbow and, being held rigid without flexion of the wrist, the

penpoint tends to describe an arc causing a different slant to be made with the same movement at successive positions in the line. Or the forearm may be held rigid with the hand, flexing at the wrist and describing a short arc, in which case the change of slant will be necessarily made within a short distance. The correction will be effected by a proper movement of the arm sideways on the muscle pad as a pivot and an adjustment of the wrist so as to secure the proper angular relation of the hand to the line at every point.

In Fig. 21 (part IV) a very desirable slant is shown.

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5. Coordination. This is one of the most important of the characteristics of good penmanship. Incoordination is of two types. In Fig. 22 (part I) the drawing type is shown, here called "wavering". In this case there is a hesitating progress showing uncertainty of movement. A child may exhibit very good

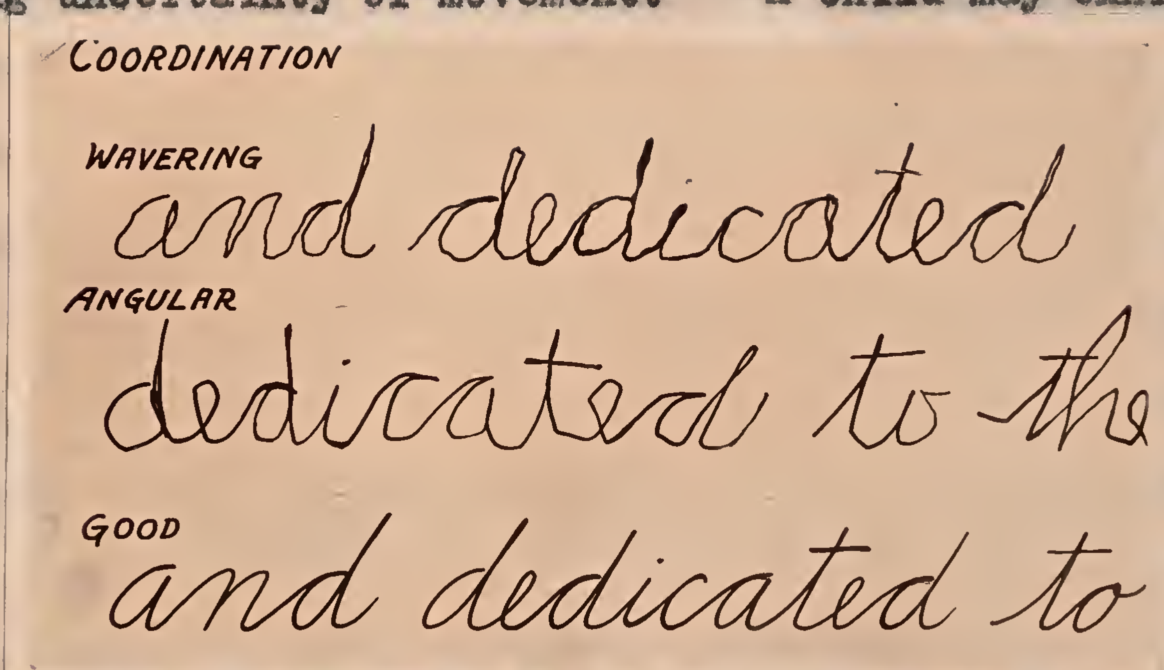

Fig. 22. Samples of Handwriting Showing Types of Incoordination and Good Coordination.

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letter form yet manifest this type of movement. Incoordination of this type is usually coupled with slow movement, though it may obtain in the case of very nervous children to such an extent as to prove irremediable. Even though this defect may

not characterize the whole product consistently it should never appear in writing beyond the primary stage. The remedy is the acquisition of quickness of movement which will make irregularity due to hesitation impossible.

The other type of incoordination, the one most commonly met with in the elementary school above the 4th Grade at least, is shown in part II of the above Figure. This is an angular type. Instead of rounding the curves in a smooth arc the writer progresses in his line of writing quite irregularly by short straight lines and angles. This fault is due to the lack of proper cooperation of the finger, wrist and arm muscles used in writing. The fault usually does result in poor letter form, though not necessarily so. The chief remedial work needed is practice in rounding curves rapidly and smoothly with the proper adjustment of muscles. A sample of writing showing good coordination is given in part III.

6. Motor Control. Lack of control of the muscles used, so that the maximum speed within a stroke is not properly placed at or near the middle of the stroke is evidenced in various ways as shown in Figure 23. If the movement gains too large a speed the stroke will be carried past its requisite length. As a result the alignment is thrown out of place, letters are misshaped, and the writing is apt to be enlarged, in whole or in part. In part I these results are evident. Also quite often a curve is rounded at too great a speed with the result that it is carried too far as in the first stroke of the "n", etc.

In part II is shown the restrained type in which not enough speed is placed on the stroke to carry it far enough. Sharp ter-

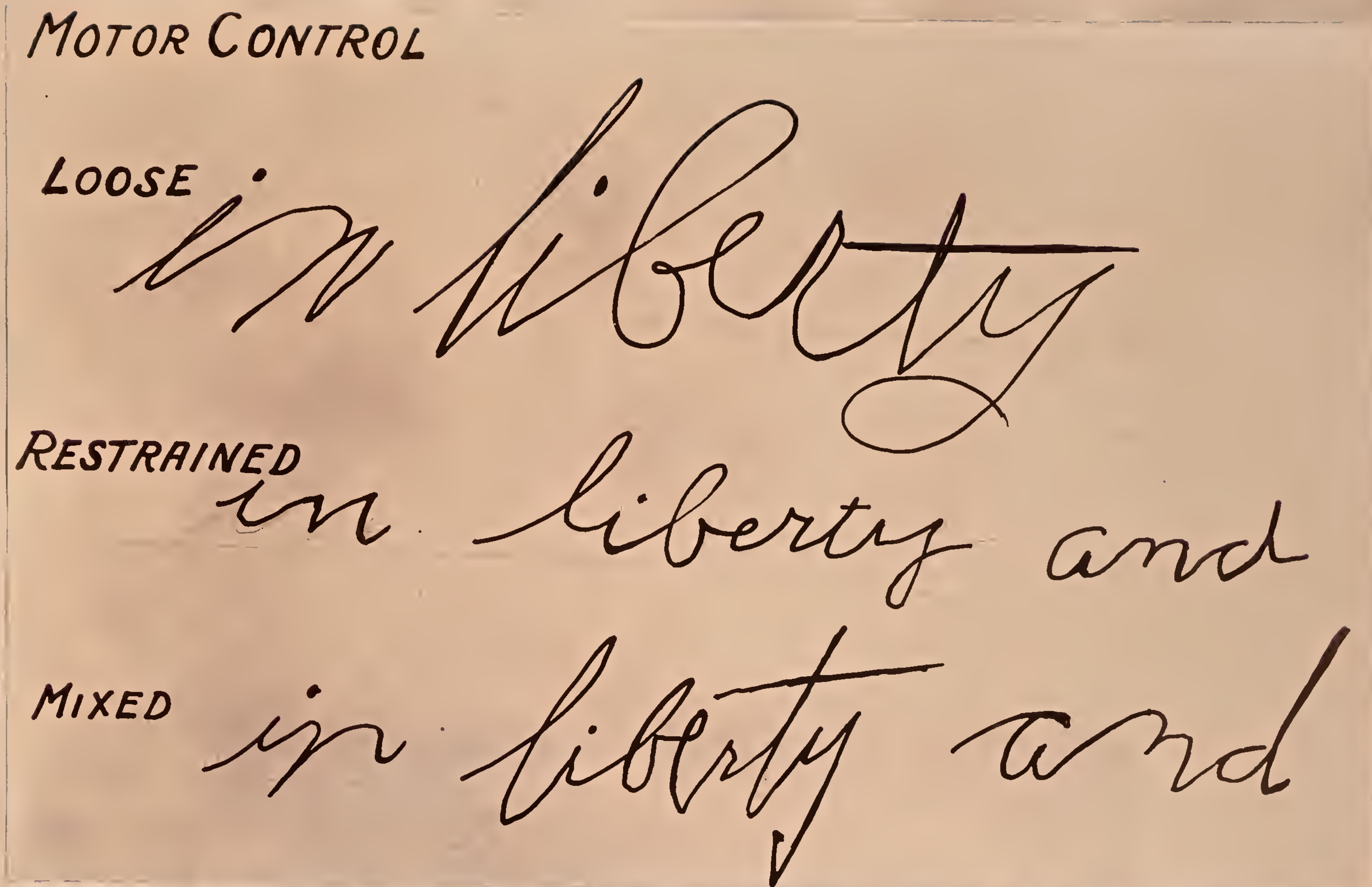

Fig. 23. Samples of Handwriting Showing Types of Defective Motor Control. (enlarged)

minagions to strokes, as the up-strokes on the "n" are common; the writing is here, as in Part I, thrown out of alinement and the whole appearance of the writing is cramped, This defect is usually coupled with incoordination, and may be the prime factor in poor letter form.

Cases frequently occur where the lack of control is of the mixed type shown in part III, in which some strokes evidence loose movement and others a marked restmaint.

The drill needed to remedy this defective control of motor elements is a careful attention to the construction of repetitive lines of a particular height or the writing of the "push and pull" exercise, or running ovals. The following of a rhythmic beat will aid in securing the proper speed and rhythmic control. The ideal is to teach the child to make a stroke of a

certain length and form with a certain habitual degree and distribution of speed emphasis. This will always evidence itself, when present, by a flowing, regular movement giving the impression of control at every stage.

7. Unit Character of the Stroke. Failure to recognize the stroke value is very common, and is evidenced by a sliding over of the important stroke elements. In the sample here given, Figure 24 (part I), the downstrokes especially do not receive their full emphasis, and are united with the stroke just preceding or following so as to not clearly define the separate strokes.

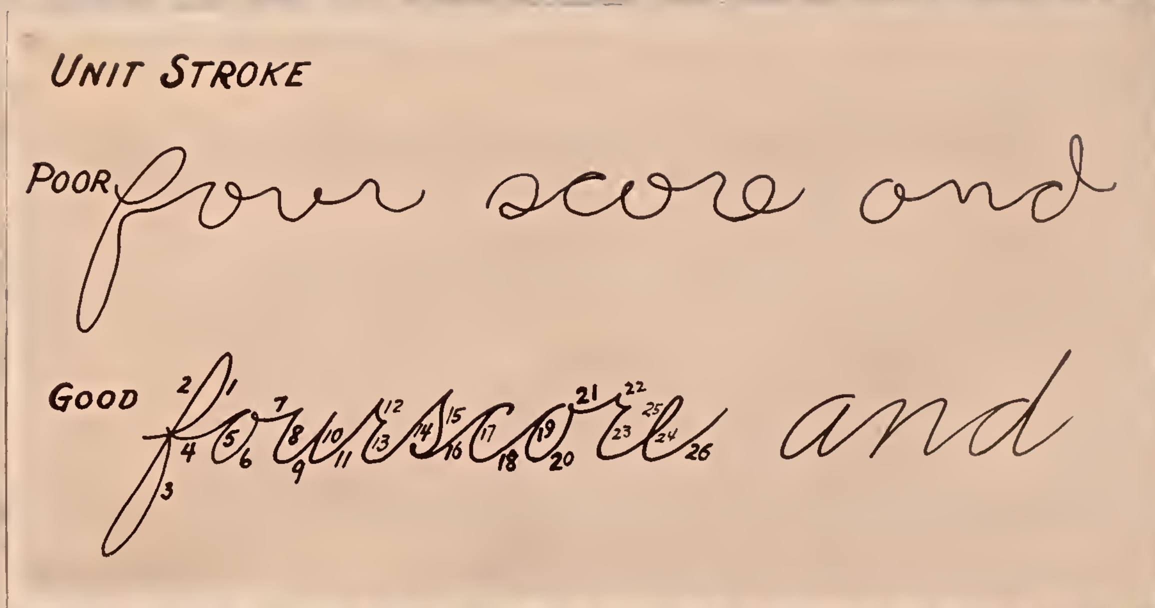

Fig. 24. Samples of Handwriting Showing the Value of Emphasis on Individual Strokes.

In part II the sample has the successive strokes in the word "fourscore" numbered in order. The cpmparison of this with Part I reveals clearly the defect of the former, stroke by stroke.

The remedy for this defect lies chiefly in calling the attention of the learner to this fault with adecuate emphasis. An aid to gaining better form at this point is found in a count on the alternate or up-strokes as the words are formed. Much of this fault is due to the attempt to speed up the writing.

and a consequent feeling that following the regular pathway of the stroke is a waste of time when one gains time by "cutting across the corners". Much of the illegibility in writing is due to this factor.

8. Spacing of words and letters. Spacing may be made consistently too narrow with a consequent illegibility, though the letter form, slant, etc., may be of the best. A case of this kind is seen in the artificial sample.Part II of Figure 25. Habitual wide spacing of letters and words is noticeable in Part III. This is to be regretted as much for its waste of space in writing and of time in reading as for anything. Although

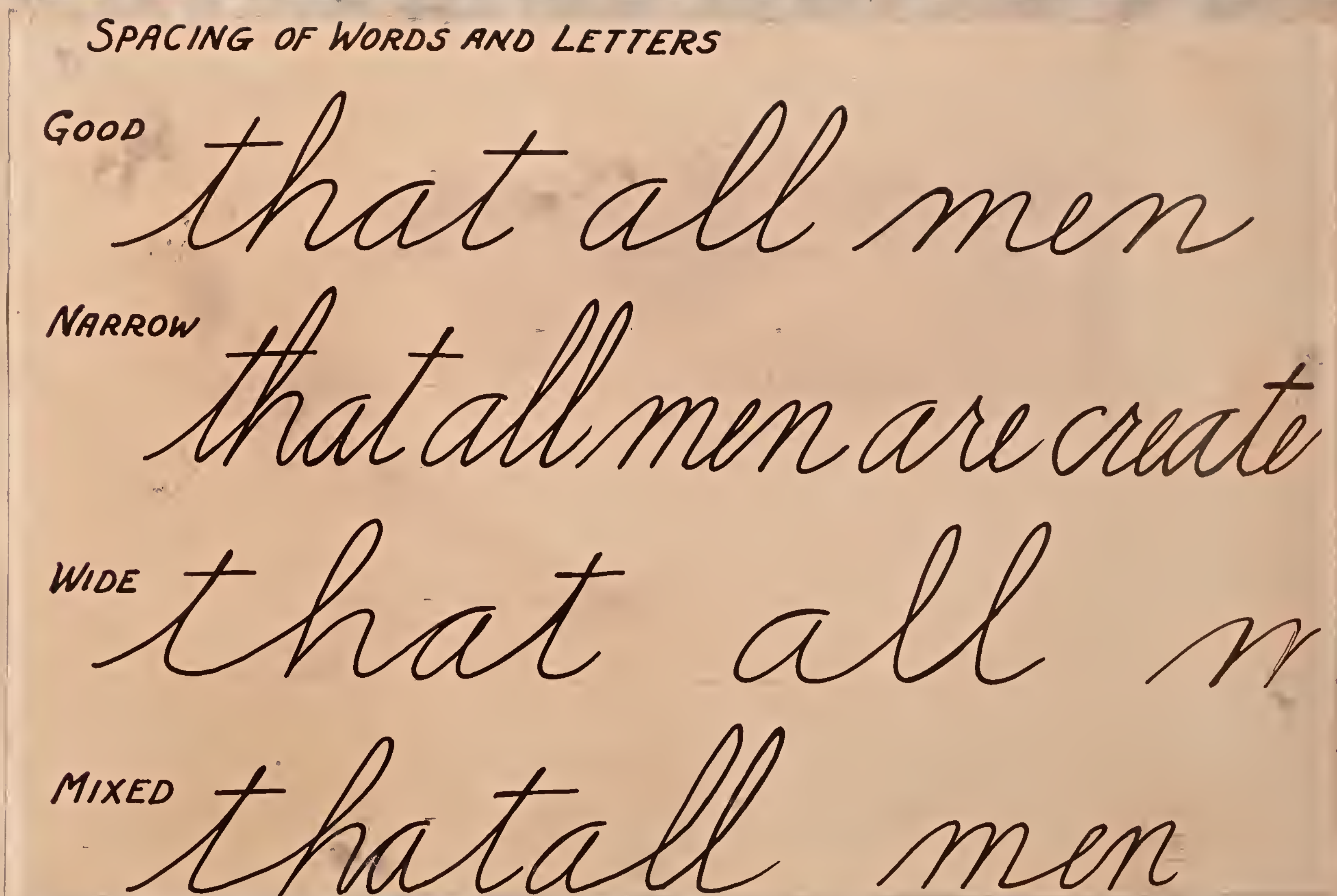

Figure 25. Samples of Handwriting Showing a Comparison of Good Spacing with Types of Poor Spacing.

cases are found frequently in which only one or the other of these two types occur, the type illustrated in Part IV is more

prevalent. Here there is no clear idea or habit of spacing either of words or letters.

Practise on the construction of simple repetitive forms, with equal and well proportioned spacing, emphatic leadership and imitation, and care in the daily work should result in improvement in most cases, though some seem to have no means of forming an adequate concept of the spatial relations involved.

9. Passage Between words. Almost no attention is commonly given to the way in which the learner effects a passage from one word to the next. It is very important however, both in point of quality and economy of time. It has been shown (p. 139 ff.) that a large fraction of the time taken in writing a passage may be consumed in this way. In Fig. 26 Part I an illustration of a poor passage between words is

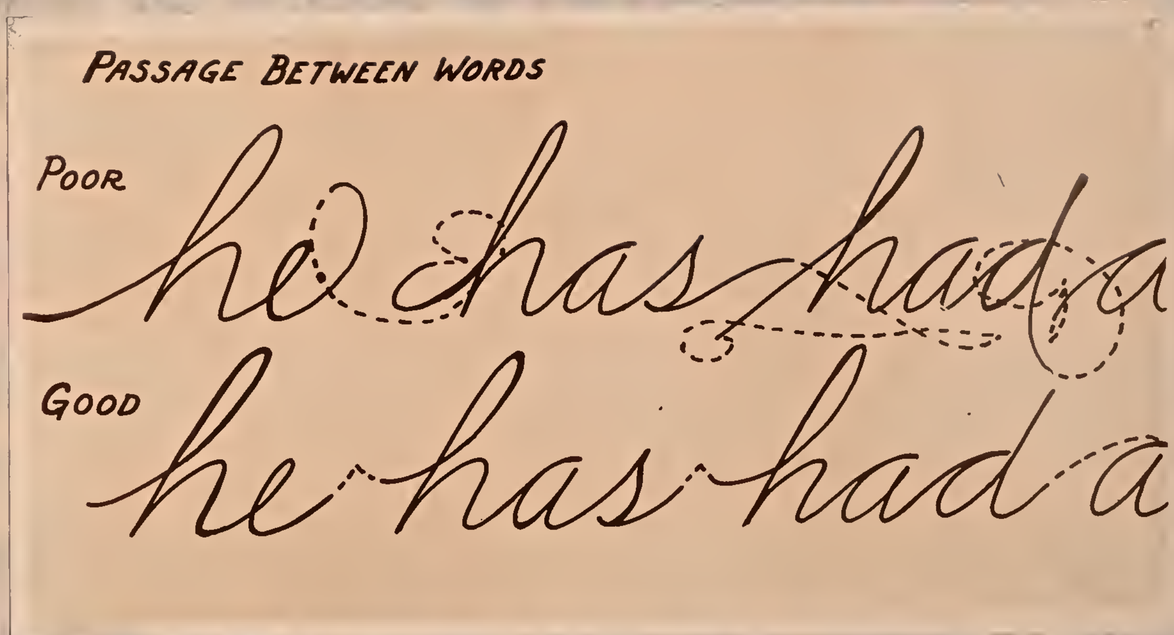

Fig. 26. Samples of Handwriting Showing a Comparison of Indirect and Direct Passage between Words.

given. The pathway of the penpoint is shown by means of dotted lines. In the sample here shown there is an evident flourish and unfortunate types of final and beginning strokes which usually accompany this fault. Another phase of this defect is when the writer lifts his arm abruptly and shifts it to a new position

but this too usually is evidenced in the product by the form of the final and initial strokes. The crossing and dotting of letters introduce unfortunate regressive movements at the end of many words which tend to augment the tendency to wasteful movement. Part II illustrates how direct passage may be effected in such a way as to secure economy as well as good closing and initial strokes. The child should not get the habit of shifting his arm, or making aimless or flourishing movements at this point. Practice in writing groups of words continuously without lifting the pen from the paper will be effective in introducing the idea of such direct passage to the child, and giving him some skill in executing it. The type of arm movement recommended for correction of slant (p.170) will prevent the shigting of the arm between words as noted on pp. 143-4.

PLAN OF A PRELIMINARY EXPERIMENT IN DIAGNOSIS
AS AN AID TO PENMANSHIP INSTRUCTION.

In the spring of 1922 cooperation of several teachers of the Fifth Grade in Kansas City, Kansas was secured through Mr. R.L.Wise, Director of Tests and Measurements. Four teachers tested the children of their rooms in Penmanship, getting samples of writing according to the demands of the Ayres Scale.(Gettysburg Edition). These samples were sent to the writer who scored all of them both in speed and quality as graded by the Ayres scale. With these samples were also sent samples of the daily school work..writing in other subjects. These also were scored as to quality. Two of these classes were chosen

for experimental work and two for control groups. All the papers were then analyzed in detail for evidences of all the above noted defects. Recommendations were then made to the teachers of the experimental rooms regarding the particular needs of the pupils of the pupils individually and as a whole. The children were then grouped by the teachers for penmanship drill according to these recommendations. After a month had passed another test was made by the teachers in the experimental rooms and the papers were sent as before and graded and analyzed, and on the basis of these papers further recommendations were made. Just before the close of school a final test was made of all the rooms, both in the experimental and the control groups, and these were scored.

The teachers in the experimental rooms were provided with large charts of the samples found in the Figures 20-26 above and were given an indication of the types of exercise suitable for the treatment of the defects found. The children studied the charts with a view to learning what defects they were tp avoid, and according to the teachers found the charts very helpful. The regular penmanship lessons of the city schools were followed.

The results were not conclusive, partly because of the few classes involved and partly because the final test was given so near the close of school that it was spoiled by the haste and confusion of the occasion and few really representative papers were gotten from any of the groups. The plan was found feasible however and will be again applied to a larger group, under better controlled conditions and

with greater freedom in the modification of the course of study.

The records of the pupils were kept in a tabulation as follows.

Pupil	I (1)	I (2)	II	III (1)	III (2)	IV (1)	IV (2)	IV (3)	V (1)	V (2)	VI	VII	VIII (1)	VIII (2)	IX
M.B.	40	25	72	o	-	o	-	-	o	-	*	-	*	-	*
C.B.	25	25	65	o	*	o	*	-	o	-	*	*	*	*	*

The sign (o) indicated no marked defect, (-) indicated a notable but not comparatively serious defect and the sign (*) a defect which demanded immediate attention. The key to the columns is

I..Quality of Penmanship..score in the Ayres Scale
(1) In the Penmanship Test
(2) In the daily work
II..Rate of Writing in letters per minute.
III..Habituation in letter-form
(1) No fixed image
(2) Definitely wrong image.
IV..Slant
(1) Wrong extreme slant.
(2) Mixed slant
(3) Change of slant with progress in line.
V..Incoordination
(1) Wavering, unsteady line
(2) Angular line
VI..Lack of motor control of speed distribution
VII..Lack of recognition of the Unit Stroke.
VIII..Spacing wrong
(1) Between words
(2) Between letters
IX..Indirect Passage between words.

Experiments are also being made to discover the accuracy with which a teacher may diagnose the pupil's work and the degree of variation in teachers judgments as compared with each other as well as their own previous judgments.

APPENDIX

TABULATIONS OF DATA WHICH
ARE REFERRED TO IN THE BODY
OF THE DISCUSSION BUT WHICH
ARE NOT ESSENTIAL IN THE
INTERPRETATION.

Table I

Sample of Original Tabulation of Records for a Subject

Subject____J.____ Finger Movement   Metro.Beat__50__   No.__18__

Stroke No.	SPONTANEOUS Rest Ti	Va	Stroke Ti	Va	Total Ti	Va	IMPOSED Rest Ti	Va	Stroke Ti	Va	Total Ti	Va	Var. from Met.
1.	28	1.8	20	.6	48	1.2	37	3.3	18	2.	55	1.3	25
2.	24	2.2	23	2.4	47	.2	30	3.7	25	5	55	1.3	20
3.	24	2.2	23	2.4	47	.2	31	2.7	21	11	52	1.7	15
4.	22	4.2	21	.4	43	3.8	42	8.3	17	3	59	5.3	12
5.	27	.8	18	2.6	45	1.8	33	.7	20	-	53	.7	3
6.	27	.8	18	2.6	45	1.8	31	2.7	22	2	53	.7	1
7.	32	5.8	18	2.6	50	3.2	30	3.7	21	1	51	2.7	- 3
8.	25	1.2	18	2.6	43	3.8	40	6.3	17	3	57	3.3	- 5
9.	32	5.8	18	2.6	50	3.2	27	6.7	24	4	51	2.7	-14
10.	29	2.8	19	1.6	48	1.2	39	5.3	20	-	59	5.3	-16
11.	23	3.2	22	1.4	45	1.8	26	7.7	16	4	42	11.7	-28
12.	25	1.2	24	3.4	49	2.2	39	5.3	18	2	57	3.3	-25
13.	24	2.2	24	3.4	48	1.2	30	3.7	22	2	52	1.7	20
14.	28	1.8	23	2.4	51	4.2	39	5.3	20	-	59	5.3	15
15.	23	3.2	20	.6	43	3.8	31	2.7	19	1	50	3.7	10
Total	393	39.2	309	29.6	702	33.6	505	68.1	300	30	805	50.7	212
Mean	26.2	2.6	20.6	2.	46.8	2.2	33.7	4.5	20	2	53.7	3.4	14.1
% Var.		10		9.6		4.8		13.5		10		6.3	26.3

Per Cent of time at Rest....Spontaneous 393 divided by 702 :: 56%
Imposed 505 " " 805 :: 62.8%

Table 2

PRELIMINARY STUDY OF THE CONSTANCY OF AN INDIVIDUAL'S RECORD THROUGH TWO TRIALS.

Part A. Actual Average Measures of Duration (in millimeters)

Sub.	Trial	SPONTANEOUS						IMPOSED RHYTHM					
		FINGER			ARM			FINGER			ARM		
		Rest	Stro.	Tot.	Rest	Stro	Tot.	Rest	Stro	Tot.	Rest	Stro	Tot.
W.	1.	15	20.5	35.5	9.9	26.3	36.2	17.9	23.6	41.5	15.1	27.8	42.9
	2.	18.2	22.2	40.5	14.5	25.3	39.8	18.9	23.2	42.1	15.3	26.4	41.7
	Av.	16.6	21.7	38.	12.2	25.8	38.	18.4	23.4	41.8	15.2	27.1	42.3
F.	1.	19.9	35.8	55.5	14.3	32.8	46.9	19.8	22.2	42.	14.6	27.4	42
	2.	21.6	37.9	59.3	22.	35.3	57.6	16.1	25.9	42.	15.8	26.3	42.1
	Av.	20.7	36.3	57.4	18.1	34.	52.2	17.9	24.	42.	15.2	26.8	42.
C.	1.	13.5	17.3	30.8	11.2	20	31.2	24.7	17.5	42.2	17.	25.	42
	2.	11.5	12.4	23.9	13.	14.5	27.5	21.8	20.2	42.	22.9	17.4	42.3
	Av.	12.5	14.8	27.3	12.1	17.2	29.3	23.2	18.8	42.1	19.9	21.2	42.1
P.	1.	18.2	22.3	40.5	14.1	25.4	39.5	18.6	22.7	41.3	15.4	26.	41.4
	2.	15.	15	30.	10.9	21.5	32.5	22.	20.1	42.1	13.7	28.3	42.
	Av.	16.6	18.6	35.2	12.5	23.4	36.	20.3	21.4	41.7	14.5	27.1	41.7

Part B. Per Cent of Time Spent at Rest.

Subj.	Trial	Spontaneous Finger	Spontaneous Arm	Imposed Rhythm Finger	Imposed Rhythm Arm
W.	1.	42	27.3	43.1	36.1
	2.	45.2	36.3	45.4	37.3
	Av.	43.6	31.8	44.2	36.7
F.	1.	36.	30.2	47.6	34.3
	2.	36.3	38.5	38.2	37.2
	Av.	36.1	34.3	42.9	35.9
C.	1.	43.7	56	58	40.6
	2.	48.2	47.3	51.8	54.
	Av.	45.9	51.6	54.9	47.3
P.	1.	45.	35.8	45.3	37.2
	2.	50.	33.7	53.1	32.7
	Av.	47.5	34.7	48.7	34.9

Table 3

Summary of the Average Measures of Duration (in mm.) for all Subjects under the Various Conditions of Spontaneous and Imposed Rhythm, with Finger and Arm Movement.

A....ADULTS -- Spontaneous

Group 1...Good Writers

Subj. No.	REST Fing.	REST Arm	STROKE Fing.	STROKE Arm	TOTAL Fing.	TOTAL Arm.
1.	16.6	12.2	21.3	25.8	38.	38.
2.	11.	9.2	19.1	20.8	30.1	30.
3.	22.7	13.3	24.7	28.7	47.4	41.9
4.	9.6	6.9	21.7	17.8	31.3	24.7
5.	19.7	20.4	33.8	30.5	54.	50.9
6.	20.7	9.2	13.9	19.9	34.6	29.1
7.	15.8	10.2	13.7	19.3	29.5	29.5
8.	22.9	10.2	16.2	24.1	39.1	34.3
9.	10.9	15.9	25.	30.3	35.9	46.3
10.	14.3	13.2	16.5	18.	30.8	31.2
11.	25.5	21.1	12.2	16.7	37.7	37.8
12.	14.	12.6	17.7	21.1	31.7	33.7
Total	203.7	154.4	235.8	273.	440.1	427.4
Ave.	17.	12.9	19.7	22.7	36.7	35.6

Group 2...Poor Writers

Subj. No.	REST Fing.	REST Arm	STROKE Fing.	STROKE Arm	TOTAL Fing.	TOTAL Arm.
1.	13.2	9.6	20.8	24.3	34.	33.9
2.	15.4	13.6	18.1	21.3	33.5	34.9
3.	19.5	14.2	11.6	15.9	31.1	30.1
4.	13.5	11.2	17.3	20.	30.8	31.
5.	15.2	17.	18.9	21.9	34.1	38.9
6.	26.2	21.5	20.6	23.4	46.8	44.9
7.	12.5	8.3	21.7	24.3	34.1	32.5
8.	8.2	6.9	15.8	13.1	24.	20.
9.	17.5	8.3	19.9	14.2	37.4	22.5
10.	10.9	13.9	15.7	25.4	26.6	39.4
11.	16.4	14.9	20.2	29.4	36.7	44.4
12.	34.9	16.3	16.5	19.6	51.4	35.9
Total	203.4	155.7	217.1	252.8	420.5	408.4
Ave.	16.9	13.	18.1	21.1	35.	34.
Comb. Aver.	16.9	12.9	18.9	21.9	35.8	34.8
M.Dev.	4.73	3.35	3.44	3.92	5.47	5.85
P.E.Mn.	.816	.578	.593	.672	.94	1.0009

Table 3 (cont.)

B....ADULTS -- Imposed Rhythm

Group 1.

Subj. No.	REST Fing.	REST Arm	STROKE Fing.	STROKE Arm	TOTAL Fing.	TOTAL Arm.
1.	18.6	15.4	23.5	26.6	42.1	42.
2.	23.9	19.5	18.	23.6	41.9	42.1
3.	21.4	18.	20.7	24.7	42.1	42.7
4.	18.4	18.9	19.4	23.	37.8	41.9
5.	17.9	15.8	24.1	26.2	42	42.
6.	30.3	14.4	12.1	27.6	42.4	42.
7.	21.1	16.7	20.5	25.2	41.6	41.9
8.	30.3	20.9	10.9	21.3	41.2	42.2
9.	20.4	16.5	21.7	25.9	42.1	42.4
10.	28.2	20.6	13.8	21.4	42.	42.
11.	32.9	27.4	9.	14.5	41.9	41.9
12.	20.8	15.1	21.2	26.7	42.	41.8
Total	284.2	218.2	214.9	286.7	499.1	504.9
Ave.	23.7	18.2	17.9	23.9	41.6	42.1

Group 2.

Subj. No.	REST Fing.	REST Arm	STROKE Fing.	STROKE Arm	TOTAL Fing.	TOTAL Arm.
1.	24.7	15.6	17.4	23.9	42.1	39.5
2.	29.5	25.2	12.5	19.	42.	44.2
3.	27.	22.3	14.7	19	41.7	41.3
4.	24.9	17	17.5	25.	42.4	42.
5.	16.8	21.3	22.8	20.5	39.6	41.8
6.	28.3	22.3	16.8	15.7	45.1	38.
7.	23.7	21.6	17.7	20.4	41.4	42.
8.	24.3	11.7	16.2	23.9	40.5	35.6
9.	25.5	14.7	15.8	26.3	41.3	41.
10.	28.1	18.1	14.1	23.7	42.2	41.8
11.	14.1	17.5	28.	24.7	42.1	42.1
12.	29.2	24.1	11.8	17.3	41.	41.4
Total	296.1	231.4	205.3	259.4	501.4	490.8
Ave.	24.7	19.3	17.1	21.6	41.8	40.9
Combined Average.	24.2	18.7	17.5	22.8	41.7	41.5
Mn.Dev.	4.07	3.1	3.75	2.96	.754	1.04
P.E.Mn.	.708	.535	.647	.5106	.13	.179

Table 3 (cont.)

C....CHILDREN ---Spontaneous

Group 1. Younger Children

Subj. No.	REST Fing.	REST Arm	STROKE Fing.	STROKE Arm	TOTAL Fing.	TOTAL Arm
1.	22.2	22.8	27.5	32.7	49.7	55.5
2.	25.8	20.7	38.4	21.7	64.2	42.4
3.	30	19.3	18.4	21.8	48.4	41.2
4.	18.4	18.5	12.2	19.5	30.6	38.1
5.	17.1	16.8	15.1	17.5	32.2	34.3
6.	15.3	12.6	17.4	17.4	32.7	30.
7.	16.8	12.9	22.3	26.3	39.1	39.2
8.	31.4	19.7	19.8	24.8	51.2	44.5
9.	19.2	28.5	15.6	23.4	34.8	53.9
10.	26.1	18.1	16.6	23.5	42.7	41.6
11.	16.6	12.5	18.6	23.4	35.2	36.
12.	23.8	14.9	14.3	22.9	38.1	37.8
Total	262.7	217.3	236.2	274.9	498.9	494.5
Ave.	21.9	18.1	19.7	22.9	41.6	41.2

Group 2. Older Children

Subj. No.	REST Fing.	REST Arm	STROKE Fing.	STROKE Arm	TOTAL Fing.	TOTAL Arm
1.	29.9	18.3	22.7	35.7	52.6	53.9
2.	11.1	7.1	17.6	19.6	28.7	26.7
3.	19.	17.	18.4	19.6	33.7	36.7
4.	20.2	16.	15.6	25.2	35.8	41.2
5.	16.1	18.7	23.3	25.2	39.4	43.9
6.	14.3	12.4	27.2	27.5	41.5	39.9
7.	17.8	13.5	25.9	28.1	43.7	41.6
8.	9.3	10.2	18.7	14.	27.9	24.2
9.	12.6	16.7	22.4	22.4	35.	39.1
10.	18.4	17.3	19.5	18.8	36.6	36.2
11.	11.5	13.2	19.3	19.5	30.8	32.7
12.	12.6	13.9	17.6	21.	30.2	35.
Total	192.8	174.3	248.2	276.6	435.9	451.1
Ave.	16.1	14.5	20.7	23.	36.3	37.6
Combined Aver.	19.	16.3	20.2	23.	39.	39.4
Mn.Dev.	4.81	3.36	3.86	3.59	6.92	5.51
P.E.Mn.	.83	.58	.666	.619	1.195	.9505

Table 3 (cont.)

D...CHILDREN -- Imposed Rhythm

Group 1.

Subj. No.	REST Fing.	REST Arm	STROKE Fing.	STROKE Arm	TOTAL Fing.	TOTAL Arm
1.	33.7	22.2	7.	19.9	40.7	42.1
2.	30.9	22.1	13.6	22.1	44.5	44.2
3.	26.8	19.9	14.2	23.	41.	42.9
4.	26.3	26.2	8.5	14.6	34.8	40.8
5.	31.2	16.6	10.4	20.9	41.6	37.5
6.	22.1	14.1	16.	25.	38.1	39.1
7.	28.5	23.4	15.4	21.2	43.9	44.6
8.	30.4	20.7	12.1	21.8	42.5	42.5
9.	30.7	20.4	12.5	21.	43.2	41.4
10.	28.	21.1	14.9	22.3	42.9	43.4
11.	20.3	14.5	21.4	26.9	41.7	41.4
12.	26.4	23.5	11.1	18.6	37.5	42.1
Total	335.3	244.7	157.1	257.3	493.4	502.
Ave.	27.9	20.4	13.1	21.4	41.	41.8

Group 2.

Subj. No.	REST Fing.	REST Arm	STROKE Fing.	STROKE Arm	TOTAL Fing.	TOTAL Arm
1.	24.9	19.8	17.8	20.9	42.7	40.7
2.	27.6	16.5	14.3	25.1	41.9	41.6
3.	25.8	18.8	17.1	17.4	42.9	36.2
4.	21.3	22.3	15.7	16.9	37.	39.2
5.	25.6	20.5	16.2	21.	41.8	41.5
6.	22.7	15.8	18.8	25.8	41.5	41.6
7.	22.6	12.	19.9	30.3	42.5	42.3
8.	21.3	16.5	19.7	25.	41.	41.5
9.	22.5	19.7	19.5	23.3	42.	43.
10.	30.8	22.9	11.9	19.2	42.7	42.1
11.	30.9	22.3	12.1	20.9	43.	43.2
12.	20.	26.1	21.7	15.4	41.7	41.5
Total	296	233.2	204.7	261.2	500.7	494.4
Ave.	24.7	19.4	17.1	21.8	41.7	41.2
Comb. Aver.	26.3	19.9	15.1	21.6	41.4	41.5
Mn.Dev.	3.35	2.86	3.19	2.75	1.62	1.325
P.E.Mn.	.578	.493	.55	.474	.279	.229

Table 4

INDIVIDUAL RECORDS OF RESULTS FOR EXPERIMENTATION OF PART II.

A... ADULTS -- Spontaneous Movement.

Group 1.

Percentage of Variation

Subj. No.	REST Fing.	REST Arm.	STROKE Fing.	STROKE Arm	TOTAL Fing.	TOTAL Arm	% Rest. Fing.	% Rest. Arm
1.	7.3	15.	6.2	13.9	5.4	5.6	43.6	44.3
2.	19.4	15.7	11.6	4.5	9.6	6.2	36.6	31.
3.	10.4	13.2	6.9	5.6	4.7	3.6	47.8	31.6
4.	17.8	31.9	12.3	8.2	8.4	11.	30.6	28.
5.	14.6	15.6	8.6	9.	4.4	4.	37.3	40.
6.	14.	27.	13.1	5.7	5.9	6.	59.7	31.6
7.	8.8	11.5	8.6	6.5	4.4	8.5	53.5	34.6
8.	11.1	13.9	11.5	6.2	8.9	3.8	58.6	29.7
9.	21.4	30.5	13.9	8.1	12.2	7.8	30.4	34.4
10.	17.6	14.2	11.4	10.3	2.5	6.6	42	46.4
11.	9.5	9.9	15.3	13.4	8.5	8.7	67.7	55.7
12.	12.4	19.7	6.4	12.6	6.4	5.3	44.1	37.4
Tot.	164.3	218.1	125.8	104.	81.3	77.1	551.9	444.7
Ave.	13.7	18.2	10.5	8.7	6.8	6.4	46.	37.1
Group 2.								
1.	8.9	17.2	6.1	4.6	2.9	4.9	38.8	28.3
2.	7.6	17.8	8.9	6.5	5.3	10.2	45.9	38.9
3.	10.4	9.4	19.5	17.6	4.8	7.1	62.7	47.
4.	16.1	11.3	8.	7.2	5.4	5.6	46.	51.6
5.	20.5	4.7	8.5	6.2	10.2	4.6	44.6	43.7
6.	10.	11.3	9.6	13.4	4.8	10.4	56.	47.9
7.	20.6	21.	8.3	5	11.	5.4	36.5	25.4
8.	24.4	19.8	11.1	7.9	8.6	5.	34.	34.4
9.	10.1	23.	10.	6.8	6.6	7.2	46.8	36.9
10.	26.2	6.6	9.3	5.5	5.4	5.	41.1	35.3
11.	18.4	15.7	12.6	8.4	4.5	8.2	44.8	33.6
12.	11.8	5.8	20.	6.4	5.7	3.9	67.9	45.5
Tot.	185	163.6	131.9	95.5	75.2	77.5	565.1	468.5
Ave.	15.4	13.6	11.	7.9	6.3	6.5	47.1	39.
Comb. Aver.	14.5	15.9	10.7	8.3	6.5	6.4	46.5	38.
Mn.Dev	4.74	5.38	2.85	2.67	2.1	1.75	8.47	6.78
P.E.Mn	.818	.928	.492	.46	.362	.302	1.45	1.17

Table 4 (cont.)

B....ADULTS ---Imposed Rhythm.

	Percentage of Variation								% Dev. from	
Subj.	REST		STROKE		TOTAL		% Rest		Dhe Beat	
No.	Fing.	Arm	Fing.	Arm	Fing.	Arm	Fing.	Arm	Fing.	Arm.
Group 1.										
1.	21.2	17.4	6.7	8.5	6.5	4.5	31.8	36.7	22.5	11.4
2.	21.7	10.3	5.6	6.2	12.7	6.2	57.	43.8	7.7	4.2
3.	10.3	12.3	5.5	5.2	5.	4.8	50.9	41.8	5.9	16.2
4.	11.9	30.	10.3	7.9	6.6	13.4	49.	45.2	19.5	32.9
5.	10.9	10.8	7.3	6.9	6.1	6.1	42.3	38.1	19.3	10.
6.	11.4	9.8	14.7	5.6	10.4	5.3	71.4	34.5	5.9	15.5
7.	20.	9.7	9.	5.5	14.2	4.9	50.7	49.8	7.4	5.4
8.	15.5	25.8	20.2	21.6	9.1	4.9	72.3	49.4	6.	10.1
9.	16.7	29.6	14.3	12.5	4.7	5.4	48.2	39.	20.6	34.6
10.	8.8	8.6	5.6	9.2	4.7	6.	50.8	67.4	7.2	15.6
11.	7.6	22.	20.8	11.2	6.6	12.2	78.7	65.3	7.3	6.8
12.	15.7	15.7	10.	16.2	9.2	11.1	49.6	36	13.2	7.3
Tot.	171.7	202.	130	116.5	95.8	85.8	652.7	547.	142.5	170.
Ave.	14.3	16.8	10.8	9.7	8.	7.1	54.4	45.6	11.9	14.2
Group 2.										
1.	12.4	37.5	5.	12.7	9.1	10.	58.5	39.4	9.	6.
2.	15.4	17.5	10.2	21.4	9.	8.7	69.3	57.	10.	23.
3.	16.5	12.4	20.4	11.4	7.2	7.6	65.	53.6	-	-
4.	39.	23.6	16.7	12.4	24.4	9.5	54.9	47.3	30.5	37.5
5.	17.	11.9	10.2	6.1	8.4	7.2	42.4	48.8	34.5	36.5
6.	13.5	16.	10.	10.6	6.3	8.7	62.8	58.7	26.3	38.2
7.	7.8	17.6	12.1	10.	6.7	5.7	57.8	51.4	-	-
8.	12.1	19.	14.1	14.2	5.	14.4	60.9	32.8	31.4	46.3
9.	12.4	24.8	12.7	10.3	6.2	7.9	61.7	35.6	5.8	17.7
10.	5.6	8.	9.7	6.4	3	4.6	66.7	43.7	2.	13.6
11.	29.2	7.4	17.5	5.9	5.2	4.3	33.4	41.6	4.2	6.
12.	11.8	12.1	17.8	10.7	10.	4.9	70.9	57.6	9.2	21.5
Tot.	192.7	207.8	156.4	132.1	100.5	93.5	704.3	517.5	162.9	246.3
Ave.	16.1	17.3	13.	11.	8.4	7.8	58.7	43.1	16.3	24.6
Comb. Ave..	15.2	17.	11.9	10.3	8.2	7.4	56.5	44.3	13.9	18.9
Mn.Dev.	4.7	4.58	4.17	3.41	2.9	2.2	9.39	7.94		
P.E. Mn.	.814	.78	.71	.588	.5	.38	1.62	1.37		

Table 4 (cont)

C...Children --- Spontaneous Movement

Group 1.

Percentage of Variation

Subj.	REST		SEROKE		TOTAL		% Rest		AGE
No.	Fing.	Arm	Fing.	Arm	Fing.	Arm	Fing.	Arm	Yrs. Mo.
1.	25.1	24.3	36.9	16.2	24.3	6.9	44.6	44.1	4 -10
2.	22.	32.1	27.9	19.8	17.5	13.3	42.4	48.9	6 -11
3.	17.5	10.3	27.8	9.8	14.5	5.6	62.1	46.9	7 - 9
4.	17	15.3	17.8	13.8	7.7	6.5	60.1	49.7	8 - 2
5.	14.7	14	19.1	10.5	10.9	9.1	53.2	49	8 -10
6.	23.8	13.6	25.3	17.6	13.8	15.3	46.8	42.1	9 - 2
7.	26.	34.4	19.6	10.4	16.7	11.8	42.9	33.	9 - 6
8.	15.5	21.8	17.1	12.4	8.8	9.8	61.5	44.3	9 - 9
9.	26.2	25.1	30.7	30.	15.	7.9	60.5	53.6	10 - 4
10.	22.3	14.7	16.8	11.8	16.9	3.6	61.1	43.6	10 - 7
11.	10.6	19.1	6.9	7.8	4.3	8.1	47.5	34.8	10 - 8
12.	40.7	16.1	43.6	13.2	14.	7.4	62.4	39.3	10 -10
Total	261.4	239.8	289.3	173.3	164.4	105.3	645.1	528.3	107 - 4
Ave.	21.8	20.	24.1	14.4	13.7	8.8	53.8	44.2	8 -11
Group 2.									
1.	11.7	6.9	8.9	10.4	6.2	7.1	56.8	33.9	11 - 1
2.	20.5	31.7	12.7	9.3	13.6	9.7	48.8	26.7	11 -11
3.	19.9	17.6	24.2	11.5	21.3	9.8	50.8	46.5	12 - 6
4.	12.3	7.	13.9	7.8	4.7	6.6	56.3	36.9	13 -10
5.	11.8	16.	11.4	12.2	8.1	9.9	40.9	42.6	14 - 3
6.	10.1	16.2	6.4	8.4	4.9	8.	34.5	31.1	15 -
7.	19.	20.4	118.2	9.9	14.9	4.3	40.8	32.5	15 -10
8.	16.5	11.5	9.	6.7	7.8	7.2	33.2	42.1	16 -
9.	23.9	15.2	15.	11.3	8.4	9.1	36.	42.7	16 - 3
10.	10.1	8.2	16.6	10.	9.1	5.9	48.5	47.9	16 - 9
11.	22.3	20.8	11.2	10.1	7.5	9.4	37.4	40.3	17 -
12.	17.9	18.4	8.4	6.3	10.1	7.8	41.6	39.8	17 - 3
Total	195.9	189.9	155.9	113.9	172.4	94.8	515.6	465.	177 - 2
Ave.	16.3	15.8	13.	9.4	14.4	7.9	43	38.7	14 - 9
Comb. Ave.	19.	17.9	18.5	11.9	14.	8.3	48.4	41.4	11 -11
Mn.Dev.	5.25	5.8	7.32	2.93	4.71	1.98	8.45	5.3	
P.E.Mn.	.905	1.	1.262	.505	.811	.342	1.46	.914	

Table 4 (cont.)

D....CHILDREN -- Imposed Rhythm.

Group 1.

	Percentage of Deviation								% Dev. from Beat	
Subj. No.	REST Fing.	REST Arm	STROKE Fing.	STROKE Arm	TOTAL Fing.	TOTAL Arm	% Rest Fing.	% Rest Arm	Fing.	Arm
1.	27.2	16.9	28.8	22.8	20.9	15.5	82.7	51.5	23.8	37.5
2.	17.1	39.8	17.1	25.1	10.2	14.1	69.2	54.3	31.8	21.2
3.	14.7	13.8	16.3	12.6	10.2	11.2	65.6	46.5	16.9	11.8
4.	12.	13.9	16	15.9	10.2	8.6	72.7	64.2	37.9	21.7
5.	32.	14.9	24.3	11.6	18.8	12.3	75.3	44.3	10.4	34.9
6.	14.1	21.9	13.9	24.3	9.5	20.2	61.	35.8	31.4	27.1
7.	18.2	19.2	12.7	12.5	8.5	7.6	64.9	52.4	29.2	31.9
8.	14.9	32.8	22.5	9.8	9.1	17.4	71.4	51.2	17.3	27.9
9.	22.9	24.8	46.7	31.2	15.7	10.5	73.9	49.3	12.2	8.7
10.	21	32.	16.9	12.9	9.7	12.8	65.3	48.8	22.6	17.2
12.	17.8	27.4	17.3	17.6	7.4	8.	70.3	55.7	26.9	21.4
11	17.6	19.6	14.	10.6	11.	9.1	48.7	34.9	17.1	14.4
Total	223.6	274.9	245.	206.9	141.2	147.3	821.	588.9	277.5	275.7
Ave.	18.6	22.9	20.5	17.2	11.8	12.3	68.4	49.7	23.1	22.9
Group 2.										
1.	26.	20.3	17.8	14.6	12.9	15.8	58.3	38.7	15.5	18.3
2.	19.5	30.3	13.8	24.3	12.4	5.2	66.	39.7	15.8	7.3
3.	14.	29.9	20.	17.3	8.6	22.9	60.1	52.2	10.9	34.2
4.	9.4	9.6	14.7	12.	6.2	8.5	57.8	56.2	29.5	28.
5.	16.9	26.8	9.2	20.2	8.6	7.8	60.7	49.1	15.9	20.4
6.	14.5	11.2	16.8	7.9	5.7	5.1	55.	33.	7.6	8.2
7.	12.3	24.1	10.4	8.	7.8	7.8	53.1	27.9	10.5	41.
8.	8.6	19.6	9.2	10.8	7.8	7.1	51.8	39.8	7.2	8.6
9.	23.6	10.2	17.2	10.3	10.2	8.9	53.5	45.8	9.3	9.4
10.	13.	29.9	26.5	16.9	5.2	9.1	72.1	54.4	4.7	10.4
11.	13.5	23.9	18.9	15.4	9.8	10.1	71.8	51.7	10.2	9.4
12.	14.4	25.2	11.5	20.6	9.9	8.2	47.9	62.4	7.6	9.9
Total	185.7	261	186.1	178.3	105.1	116.5	708.1	565.9	144.7	205.5
Ave.	15.8	21.7	15.5	14.9	8.8	9.7	56.5	47.2	12.6	17.1
Comb. Ave.	17.2	22.3	18.	16.	10.3	11.	62.4	48.4	17.8	20.
Mn.Dev.	4.58	6.91	5.14	4.97	2.53	3.6	7.85	6.67		
P.E.Mn.	.78	1.192	.89	.857	.436	.62	1.35	1.15		

Table 5.

CORRELATION OF AGE OF CHILDREN WITH THE PER CENT
OF THE TOTAL STROKE PERIOD SPENT AT REST.
(Pearson Method by Grades)

SPONTANEOUS						IMPOSED RHYTHM					
Finger Movement.						Finger			Arm		
RANK			RANK.			RANK			RANK		
% Rest.	Age.	+ Dev.	% Rest	Age	+ Dev.	% Rest.	Age	+ Dev.	% Rest.	Age	+ Dev.
1	20	19	1	14	13	1	24	23	1	21	20
2	18	16	2	18	16	2	11	9	2	10	8
3	21	18	3	19	16	3	20	17	3	6	3
4	23	19	4	7	3	4	19	15	4	19	15
5.	19	12	5	13	8	5	21	16	5	14	9
6.	19	13	6	11	5	6	18	12	6	18	12
7.	24	17	7	16	9	7	16	9	7	5	
8.	22	14	8	12	4	8	13	5	8	17	9
9.	2		9	24	15	9	15	6	9	4	
10.	1		10½	23	12½	10	18	8	10	13	3
11.	6		10½	6		11	6		11	11	
12.	11		12	20	8	12	7		12	20	8
13.	22	9	13	17	4	13	10		13	9	
14.	14		14	21	7	14	3		14	7	
15.	15		15	10		15	14		15	2	
16.	5		16	1		16	2		16	23	7
17.	16		17	8		17	12		17	16	
18.	13		18	15		18	8		18	8	
19.	4		19	3		19	23	4	19	1	
20.	9		20	22	2	20	22	2	20	22	2
21.	10		21	4		21	4		21	12	
22.	8		22	2		22	9		22	15	
23.	3		23	5		23	6		23	24	1
24.	12		24	9		24	1		24	1	
Tot.		136			122½			126			97

R =: -.419
r ..-.641 .08

R...-28
r...-.458 .109

R..-315
r..-.507 .104

R..-.612
r..-.01

Table 6

CORRELATION AMONG ADULT RECORDS OF THE PER CENT OF THE TOTAL PERIOD SPENT AT REST AND THE PER CENT VARIATION IN TIME SPENT AT REST.

SPONTANEOUS RHYTHM

Finger Movement				Arm Movement.			
	RANK				RANK		
Subj. No.	Var. %	Rest %	+ Dev.	Subj. No.	% Var.	% Rest	+ Dev.
1.	1	10	9	1	12	18	6
2.	19	5		2	14	5	
3.	8	17	9	3	9	6	
4.	17	2		4	24	2	
5.	14	6		5	13	16	3
6.	13	21	8	6	22	7	
7.	3	18	15	7	8	11	3
8.	10	20	10	8	10	4	
9.	22	1		9	23	9	
10.	16	9		10	11	21	10
11.	5	23	18	11	5	24	19
12.	12	11		12	18	14	
13.	4	7	3	13	16	3	
14	2	14	12	14	17	15	
15.	9	22	13	15	4	20	16
16.	15	15		16	7	23	16
17.	20	12		17	1	17	16
18.	6	19	13	18	6	22	16
19.	21	4		19	20	1	
20.	23	3		20	19	10	
21.	27	16	9	21	21	13	
22.	24	8		22	3	12	9
23.	18	13		23	15	8	
24.	11	24	13	24	2	19	17
	Total		132			Total.	131

R... -.378

r... -.591 ±.085

R... -.365

r... -.573 ±.092

Table 6 (cont)

IMPOSED RHYTHM.

Finger Movement				Arm Movement			
	RANK				RANK		
Subj. No.	% Var.	% Rest	+ Dev.	Subj. No.	% Var.	% Rest	+ Dev.
1.	21	1		1	14	5	
2.	22	12		2	6	12	6
3.	5	10	5	3	10	10	
4.	9	6		4	23	13	
5.	6	3		5	7	6	
6.	7	22	15	6	5	2	
7.	20	8		7	4	16	12
8.	15	23	8	8	21	15	
9.	18	5		9	22	7	
10.	4	9	5	10	3	24	21
11.	2	24	22	11	18	23	5
12.	16	7		12	12	4	
13.	11	14	3	13	24	8	
14.	14	20	6	14	15	21	6
15.	17	18	1	15	11	19	8
16	24	11		16	19	14	
17.	19	14		17	18	17	
18.	13	17	4	18	13	22	9
19.	3	13	10	19	16	18	2
20.	10	15	5	20	17	1	
21.	12	16	4	21	21	3	
22.	1	19	18	22	2	11	9
23.	23	2		23	1	9	8
24.	8	21	13	24	9	21	12
	Total		119		Total		98

R..... -.242 R... -.023

r.... -.402 ±115 r... -.041

APPROVED:

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Date____________________________